GENERAL MOTORS

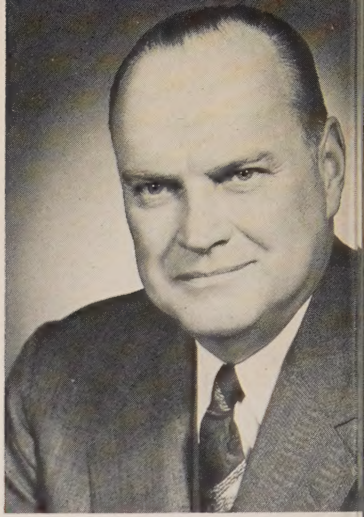
Engineering JOURNAL

Volume 2 July-August 1955 Number 4

for educators in the fields of engineering and allied sciences

ENGINEERED FACILITIES

Some Thoughts on Marketing



A HARVEST, according to Webster, is the product or reward of effort. The harvest of engineering effort is gathered in the market place. As the ancient Greeks voted on important issues in the *Agora*, or market place, so today's citizen votes his approval there of the value built into a company's product.

Our modern merchandising marts are far removed from the ancient *Agora*. Yet, today's tourists can still find some primitive markets where they may watch a native skillfully deliberate the price of his product. In this agreeable wrangling, the customer and seller conduct a spirited debate in well-established patterns with rules familiar to both. The native has no set price parameters because his product costs him, primarily, his personal labor. Modern industry cannot afford such distributive simplicity—although at the point of sale involving a trade-in automobile there may be a spirited debate.

In present-day production, both material and labor are costly factors. Reduction in overall cost both as it affects material in the product and its processing depends importantly on engineering. Yet improvements produced in the laboratory would remain imprisoned there unless released through the avenues of production—of which engineering and manufacturing are two important ones—into a robust distribution system.

Even the finest engineering needs to blend with sound merchandising to produce a balanced operation. The automotive industry relies strongly on dealers' initiative in selling and servicing products. To implement dealer efficiency, General Motors has established training centers to actively instruct service personnel in the technical features of new models. This activity supplements other training programs directed by the GM Divisions concerned to aid dealers in keeping pace with the automobile's engineering complexity.

Customer research is another activity in which engineering ideas have an anchorage. Polls conducted to determine customer likes and dislikes inform engineering where to initiate new technical programs and improve existing ones. Information culled from market-research tallies also helps in stabilizing production schedules.

Under industry's energetic emphasis on technological improvement, more attention is paid to marketing to avoid waste. Over the years, General Motors has continually improved its distributive methods. The network of assembly plants, warehouses, dealerships, training centers, and other distribution facilities is laced with many engineering activities. Even traffic and transportation, the sinews of the distribution system, benefit from the spread of technological progress.

There is an old saying that "the sharper the chisel, the more wood it is likely to cut." If a company technically sharpens its products, it will cut a large slice of the market.

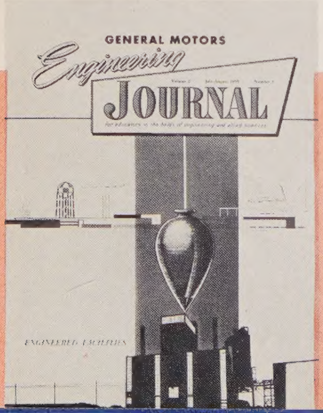
The automotive business today—as throughout its history—is highly competitive. Nevertheless, the industry is feeding on the fullness of an expanding market due to the impact of engineering improvements and the momentum of changing social and economic factors. The shift to suburban areas has introduced a highly mobile population. The still-growing influence of women on the automotive market and the increasing life span of our population have stretched the years of potential buying.

Along with these influences has come increased purchasing power which shows every indication of continuing as the productivity per man-hour rises. However, it takes more than plentiful production to satisfy an expanding market; only the best possible product will clinch a large share of it. With the best possible product must go the distribution system which gets it to the users when and where they want it.

In sum, the harvest of engineering is gained by users of the end product. There can be no harvest without the distribution function.

W Hufstader.

William F. Hufstader,
Vice President in Charge
of Distribution Staff



THE COVER

The ever-forward technological advances in an industrial organization such as General Motors require continual expansion in manufacturing facilities to keep pace with progress. In this month's cover design by artist John B. Tabb, the plumb bob symbolizes the engineering behind the planning, development, installation, and supervision of the physical facilities required for the manufacture of General Motors products. Construction of buildings, power generating or distribution equipment, and waste disposal systems are typical projects in which GM engineers engage to provide adequate capacity for future production of automotive and non-automotive products. Much of this kind of work is currently being done as a part of General Motors' program of capital expenditures, now in its second year. Recent action increased the total program to 2 billion dollars announced since January 1954.

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A Summary of High-Speed Special Assembly Machinery Developed at Delco-Remy

By **CHARLES A. NICHOLS** and **WILLIAM A. FLETCHER**
Delco-Remy
Division

Tracing the genealogy
of special
assembly machinery

Management is always alert for ways to reduce operating costs and improve product quality. During recent years, the increasing introduction of special production machinery has proved a useful tool in cutting production costs, but there have been relatively few such special machines developed with enough flexibility to cover the variable combinations of assembly operations. One deterrent to progress in development of special assembly machines has been the need to standardize such machinery so that its application in mass production is economically sound. Yet, this standardization must be adaptable to meeting product re-design successfully. At Delco-Remy Division, semi-standard, automatic assembly equipment has been developed through careful evaluation of these factors and has been used effectively on the assembly line. Experience gained so far has established a design approach for future models.

A STUDENT in a university might turn one armature shaft on an engine lathe, just as would a production man for an experimental design. In industry, if the requirement were for 100 identical shafts, production might be by means of an automatic lathe or a hand screw machine. For a total production schedule of 10,000 shafts, a multiple-spindle, automatic screw machine would be the logical equipment to use. A manufacturing methods engineer would accept these solutions as rational—in keeping with the design and number required. What happens when not 10,000 total, but 10,000 or more daily, are required has already been recorded.[1]

In that instance, greater efficiency was achieved through a mutual study of the part by the product and the production engineers. Entirely new concepts of fabrication were successfully undertaken by designing a shaft to use a welded steel tube rather than a solid bar, achieving a substantial savings in materials and manpower. Whether the daily requirement is for one piece or 10,000, the process development engineer's goal is the same—to arrive at the optimum man-machine relationship. When the number needed is small, man's muscles carry a greater proportion of the load than when the quantity to be made is great.

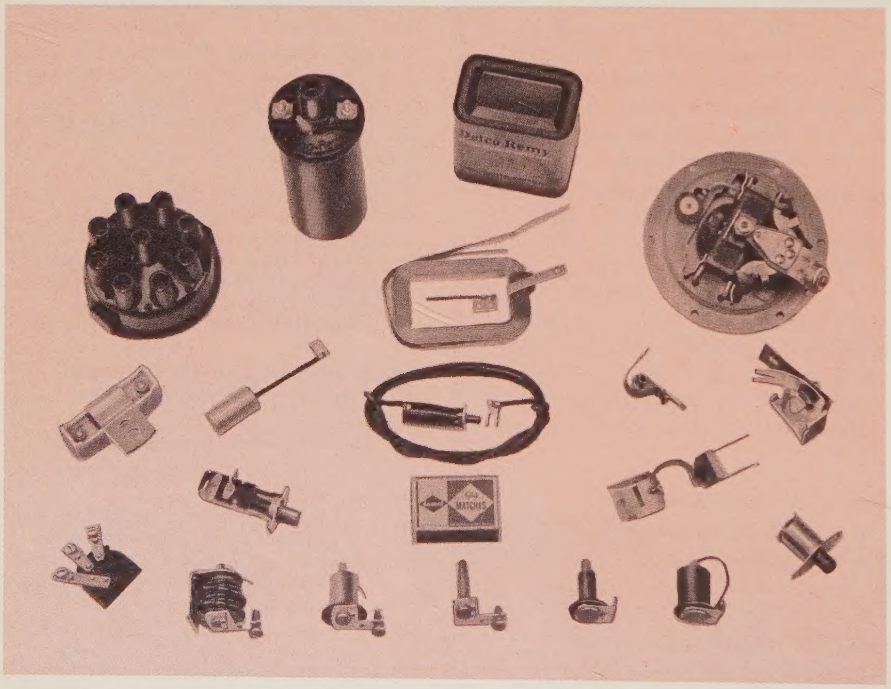


Fig. 1—These parts are typical of the work processed on Delco-Remy Division's in-line machines which demonstrate the machines' adaptability in meeting the variable requirements of some of the 500,000 assemblies produced daily.

The making of parts is difficult at times, but assembly operations often prove even more complicated. There are few standard machines for assembly operations which compare in effectiveness, for example, to an automatic screw machine. The temptation—if not the necessity—of specifying hand assembly is always present, except to engineers who think in terms of special machines. Process development engineers are always alert to the possibility of developing a new machine to supersede hand assembly work. Such machines are called *special* because no conventional machine exists to handle the operations involved, which may be unique to one single assembly requirement. Human and economic factors are determinants of when it might be worth-while to expend the technical effort needed to develop special machines.[2] An oversimplified criterion is that a special machine becomes feasible if it is technologically possible to make it and if its use can be more than amortized by anticipated savings in actual operation. This logic applies, of course, both to machines used to make parts and to those which assemble the parts. Opportunities for engineering advancement are always present in both areas, but the greater challenge seems to rest in the development of special machines for assembly operations, because of the aforementioned tendency toward unique requirements.[3]

The Economics Behind Special Assembly Machinery

At Delco-Remy Division, during a period of more than twenty years, considerable experience has been gained in the development of production assembly machines, and in reaching the decision as to when an assembly machine is justifiable. Many such machines have started as special machines, but wide usage within and outside the organization have made many of them conventional assembly machines. The assembly task has grown to large proportions in this Division, where 10 plants are in operation in Anderson, Indiana, 1 in Muncie, Indiana, 1 in New Brunswick, New Jersey, and 1 in Anaheim, California. A standard day's output at Anderson is 500,000 assemblies, including cranking motors, generators, ignition distributors, ignition coils, current and voltage regulators, relays, switches, solenoids, condensers, and controls of various kinds. Because of the complex nature of these assemblies, they require a far greater number of parts than would be needed for structural shape and strength alone. The assemblies have an average weight of about 24 oz and one typical General Motors car has 19 units made in Anderson, blending a total of 1,376 individual parts.

The field for development of special assembly machines has been explored with satisfying results. More than 1,000 special machines of various types have been built to date. Commutators, ignition coil winding, and other parts of rather stable design have warranted development of most of the equipment (Fig. 1). The yardstick of economic justification always has been applied. Because of this factor, many operations remain conventional inasmuch as they involve items of short-duration design and low production.

The challenge to process development engineers seems to be in making special machines which are also versatile and, thus, semi-standard. Assembly for one model-year of a component might not justify development of new equipment, but new machinery would prove economical if developed so that, with little or no modification, it could handle the following year's anticipated product changes. By development of such machines, a number of short-duration design items have lent themselves to automatic assembly operations.

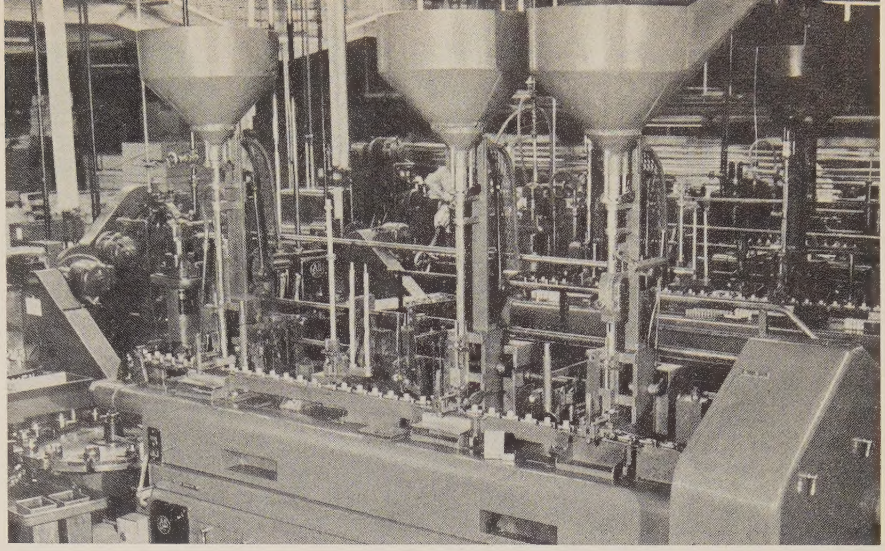


Fig. 2—This over-and-under type in-line machine is used to assemble ignition condensers. At the lower left-hand corner the finished assemblies are being inverted, then mated to hand-fed leads in the crimping dial. After this has been completed, the assemblies are conveyed to a second in-line machine where the condensers are electronically inspected and the connection clips are made, assembled, and then welded to the leads.

Development of the In-Line Type Assembly Machine

Of particular merit has been automatic assembly machinery of the *in-line type* which permits a linear flow from one operation to the next as the assemblies are built up. Thus, conventional operations can be easily injected into the assembly pattern and, ideally, two or more such machines can be arranged front-to-end, enabling many operations to be performed automatically.

The origin of these in-line assembly machines at Delco-Remy may have begun with a production engineer's visit to a plant manufacturing shotgun shells. At that time, this engineer was engaged in improving the efficiency of ignition condensers. Using ideas stimulated by what he had seen in this unrelated field, he and co-workers succeeded in developing a special condenser assembly machine which has since become a standard machine known as the in-line type. Experiences gained in its development introduced a new concept of assembly techniques in the organization, and the result has been great advancement in the usage of a wide variety of in-line assembly machines, which may be classed as semi-standard.

Basic Controls

The basic mechanism of the current condenser assembly machine remains the same today as for its predecessor of many years ago (Fig. 2). A chain track, indexed for conveying parts from station to station, is controlled automatically. Nests are attached wherever needed to the chain, to accept parts from either stacks or hoppers (Fig. 3). As each part is added, an automatic device determines whether the piece is in proper position to accept the next part. If the part is out of sequence or missing, the mechanism automatically stops and a flasher bulb indicates the station requiring human attention. Next, the finished assemblies are inverted and mated in a crimping dial to hand-fed leads. The work then moves on an inclined conveyor to a second in-line machine which electronically inspects the condenser, rejects and sorts the rejections, makes and assembles the connection clip, and welds it to the lead. These machines have justified development costs by reducing the assembly cost of the condenser, while improving the quality. They have proved, also, that the in-line machine fits well into a production plant layout.

A Design Formula for Special Assembly Machinery

The field opened up by the development of this first machine has proved fruitful, and continuing studies have progressed to the point where certain basic principles may be deduced with universal application to the design of special assembly machinery:

- A standard-type machine, with a basic pattern and auxiliaries adaptable to product re-design, is desirable.
- Overall machine length is standardized so far as possible with respect to

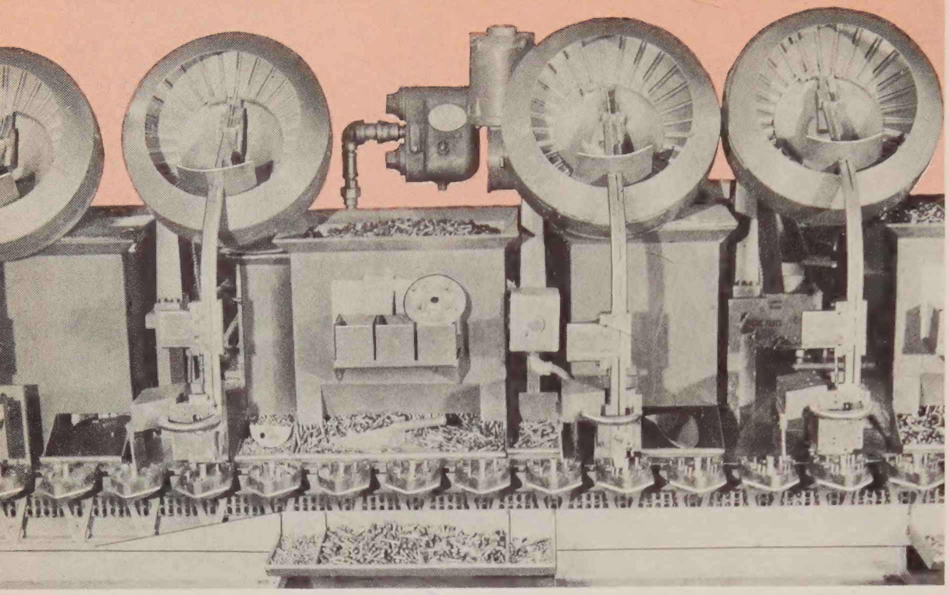


Fig. 3—Automatic feeding of parts on in-line machines may be accomplished by the use of auxiliary equipment—which in this instance happens to be four gravity hoppers.

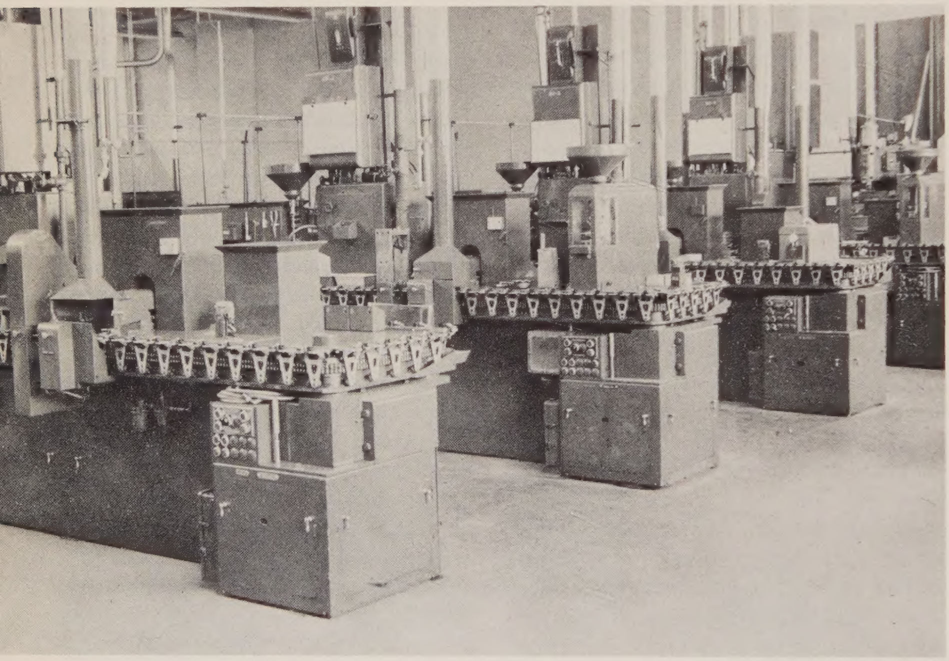


Fig. 4—This general view of several in-line machines used in the plant shows the neat appearance, some safety features, and operator convenience of the overall design.

other manufacturing equipment in the plant.

- The index portion of the cycle time is held as short as possible so that maximum dwell time is permitted for hand or machine operations—whichever the case may be.
- A simple fixture mounting provides greater replacement accessibility.
- Maximum freedom allotted to standard auxiliaries, such as welders, presses, and hopper feeds, allows greater utility.
- Overall construction achieves a good, basic standard for safe working conditions.

Holding fixtures represent a substantial portion of the machine construction costs and, therefore, are of prime interest to the designer. In any new machine development, the overall cost factor is continually balanced against ultimate economic gains. In developing special assembly machinery, automatic assembly necessitates greater uniformity of parts than hand operations, but the lower scrap loss eventually may offset the costs of higher quality parts. To reduce costs, standard, internally designed components are used wherever possible. For example, that portion of the working station fastened to the chain is standard, made up of welded press parts.

Finishing Touches

Once the basic technical pattern has been established, styling features are decided on.[1] In doing so, the comfort, safety, and convenience of the operator are taken into full consideration. Good housekeeping conditions are promoted by enclosing the machine to the floor and providing easily accessible tool receptacles (Fig. 4). Heavy, durable guards protect the operator, yet they are easily removed when servicing the stations. All steel parts are either painted or plated, and all operator tools are chrome plated.

Uses Still Expanding

At Delco-Remy, the in-line machine was developed originally as a basic assembly machine but was soon found to be capable of incorporating a variety of non-assembling functions as well. For instance, a bushing might be assembled to a lever, the bushing reamed, and further assembly operations completed. Table I lists some of the various combinations of operations performed by these machines. One typical combination of operations is that involving the circuit-breaker lever for distributors (Fig. 5). In this case, the operations performed include sorting and hopper feeding parts, staking, reaming, milling, hot upsetting, burring, and inspecting. The versatility and form of this basic assembly machine thus have expanded at Delco-Remy to the extent that 50 models are now in regular use. To capitalize fully on this development, therefore, and to maintain an up-to-date re-design program, a special department has been established for the design and construction of these machines and also for operator training. The high volume and diversity of products manufactured by the Division have enabled this department to be maintained on an economical basis.

Functioning of the In-Line Department

At Delco-Remy, this special department is referred to as the In-Line Department, and its technically trained designers are located in the same area where the machines are produced. The

PRODUCTION OPERATIONS WHICH MAY BE PERFORMED BY IN-LINE MACHINES

FUNCTIONS	OPERATIONS
MACHINING	Reaming Drilling Tapping Milling Boring
PRESS	Making, Assembling (Parts) Riveting Staking Piercing Trimming Forming
JOINING	Welding Hot Upsetting (Studs, Rivets) Soldering Heat Searing (Pressure-sensitive Materials)
PACKAGING	Printing Packaging
AUTOMATIC FEEDING	Hopper Feeding (Parts) Feeding and Driving (Screws) Applying Sealing Compounds, Lubricants
INSPECTION	Weighing, Sorting (Parts) Mechanical Checking Electrical Checking
BURRING	Removing Excess Material
CLEANING	Chip Removal

Table I—This list of combined operations shows the range of functions which may be considered to enhance the usefulness of special assembly machinery.

resulting close contact between the design and construction groups permits exploratory tryout of ideas before designing permanent auxiliary attachments.

The Department's shop is adapted to produce only those parts involving strictly developmental work. The machine bases and all other standard parts are purchased, freeing the skill of Department personnel to solve specific problems and produce only such equipment as cannot be subcontracted. In this way, greater capacity is available than if the entire machine had been produced internally. The In-Line Department relies heavily on the facilities of the Production Engineering Department, including welding, press work, electronics, and hydraulics. Close cooperation is also maintained with the Inspection Department since many inspection functions are performed by the machines. Often, the auxiliary inspection equipment is provided by the Inspection Department, then built into the machines by the In-Line Department.

As a rule, mechanics from the plant where the machine is intended to be used spend some orientation time in this Department becoming familiar with the equipment. Facilities to properly service the equipment are especially important. While the machines' productive use reduces overall labor costs, more skilled mechanics are required for servicing them.

Programming the Design Phase

In designing a new in-line machine model or revamping an old one, the Cost Estimating Department determines both the need and the economic justification after the existing production method for a new product is determined. Projected operations and tasks of the machine also are selected by this group, in consultation with the supervisor of the In-Line Department. At times, the machine performance depends upon modifications in product design.

Such proposed design changes in the parts to be assembled are based on anticipated improved production rates and improved product quality, and the necessary revisions are made after approval by the product engineers. When completed, the machine is operated at progressively increasing rates until any existing problems are worked out. Then it is studied by the Standards Department and production rates are established. When a rate has been agreed upon, the machine is put into use on the assembly line. (Production supervisors are in daily contact with the development phase of a machine for a particular assembly and, at its tryout stage, production operators are trained by production supervisors.)

A Review of Standard Types

The in-line family has three types of special assembly machines which are related by their similarity in base construction (Fig. 6). Their principal difference lies in the type of track used, which may determine such factors as the location, number, and size of auxiliaries, and operators' positions and adaptability to working conditions. The function of the chain track is the conveying of parts from station to station on fixed work-performance cycles.

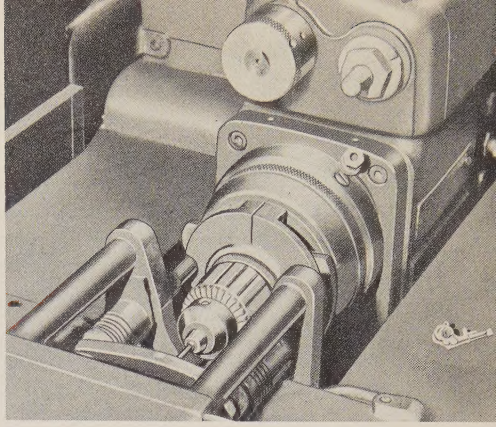


Fig. 5—The reaming of a circuit-breaker lever for distributors is a sample of the type of non-assembly functions performed by the machines. The use of such auxiliary attachments greatly increases the machines' adaptability in the assembly pattern.

Over-and-Under Type

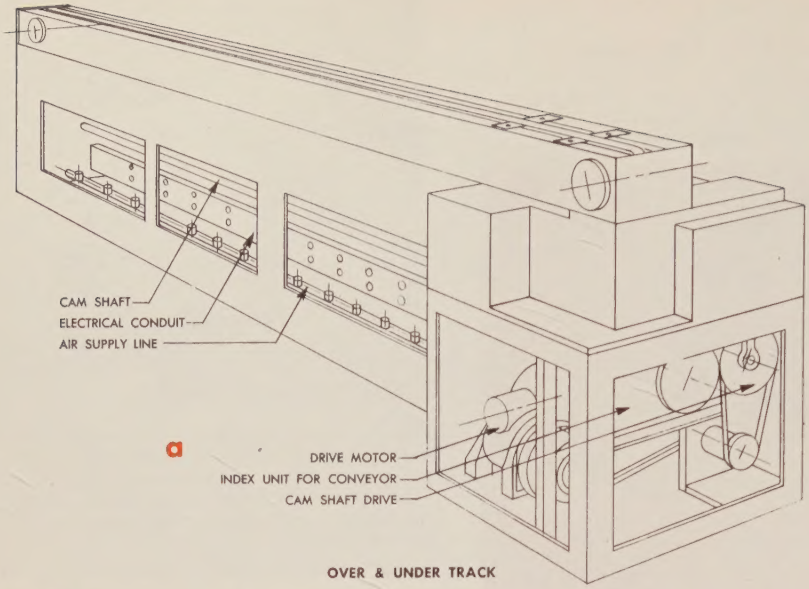
In the first machine developed, an *over-and-under type* of track was used. This restricted the usable fixtures to the top-track area, adding to the overall cost and weight of the machine. As a result, this model's range is limited and few have been built for production use.

Narrow-Track Horizontal Type

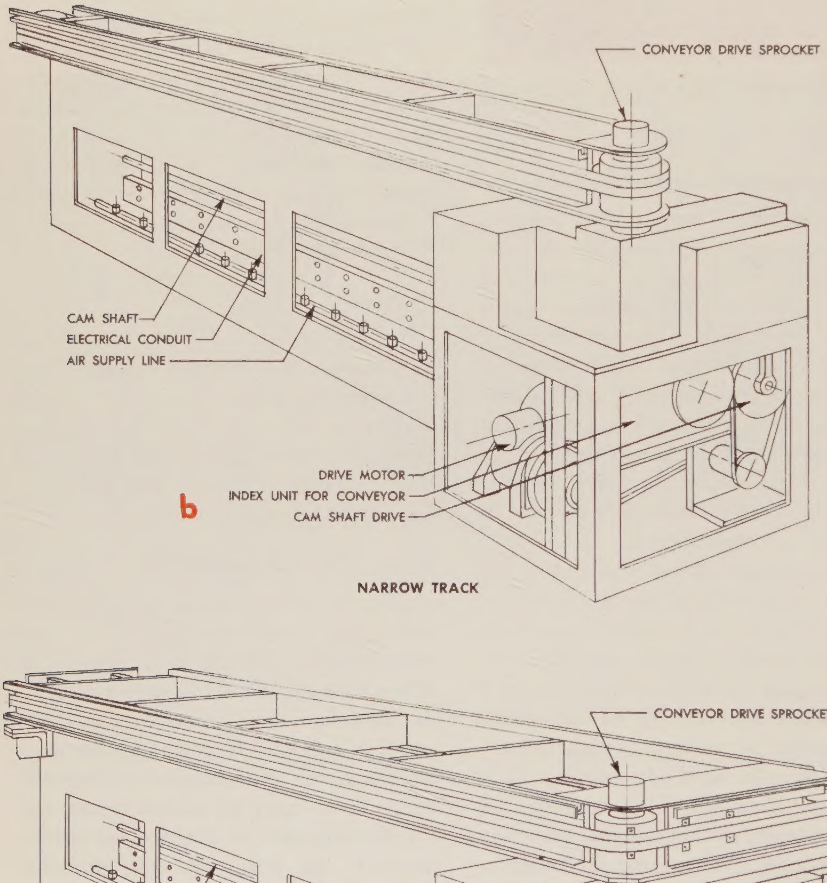
The second successful type developed was a *narrow-track* design in which the chain track operated in a horizontal plane with all fixtures readily available. In this design, large and heavy auxiliaries could be mounted directly from the floor at the rear of the machine or from the base. With hand operations performed on the front side and automatic operations at the rear, the only practical operator space remaining was at the front of the machine. While this type was an improvement on the over-and-under model and was used more often in production, a more versatile design had yet to be developed to meet the variable conditions and combinations of assembly operations.

Wide-Track Horizontal Type

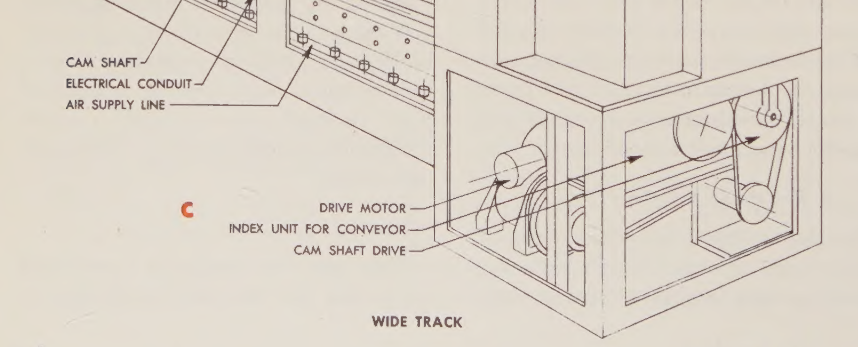
This third type produced is similar to the second, but achieves greater adapta-



OVER & UNDER TRACK



NARROW TRACK



WIDE TRACK

Fig. 6—This family of in-line machines consists of (a) the over-and-under type, (b) the narrow-track type, and (c) the wide-track type. All three designs are related by their similarity in base construction. Note the camshaft, electrical conduit, and air-supply line running the entire length of the machine, which permit connections at any desired point. (Split cams are used on the camshaft to permit easy assembly and adjustment.) Parts are conveyed by means of a chain track which is indexed automatically past each loading and checking station. Parts may be either hopper or stack fed into nests mounted at any desirable point on the chain. In the first design developed (a) the chain moves across the machine's working surface, while in the later models it moves around the working surface. The wide track of the third (c) and most popular type enables auxiliaries to be mounted either between or outside the tracks, and hand and automatic operations may be modified as each job requires.

bility with a wider chain track. This wider track permits auxiliaries to be mounted either between or outside the tracks. Hand and automatic operations may be modified as the work requires. The indexing drive unit is located at one end of the machine, and running the length of the machine are the camshaft, electrical conduit, and an air-supply line which serve the auxiliaries. (Connections may be made at any point along these service units.) Cams are of the split-design type and can be removed or adjusted easily. The machine uses a standard electrical control panel mounted for easy access. The overall length of the machine is standardized at 14 ft—a dimension which has accommodated most of the assemblies produced at Delco-Remy. Generally, as many as seventy-five fixtures are mounted on a standard *wide-track* machine, and production rates up to 1,600 per hr have been maintained. Several years' experience with these machines has verified their low maintenance cost, and the anticipated chain stretch has been found of little consequence.

This design has proved the most popular and useful of the three developed to date and several models have been built, all using the same standard base construction.

Indexing Mechanism

One of the most vital components of a special assembly machine is its index mechanism which has to be designed for smooth action to maintain parts steady in the fixtures (Fig. 7). The movement of parts from work station to work station and the automatic assembly operations must be carefully synchronized so that adequate time is allotted to each. Index accuracy may be improved by providing

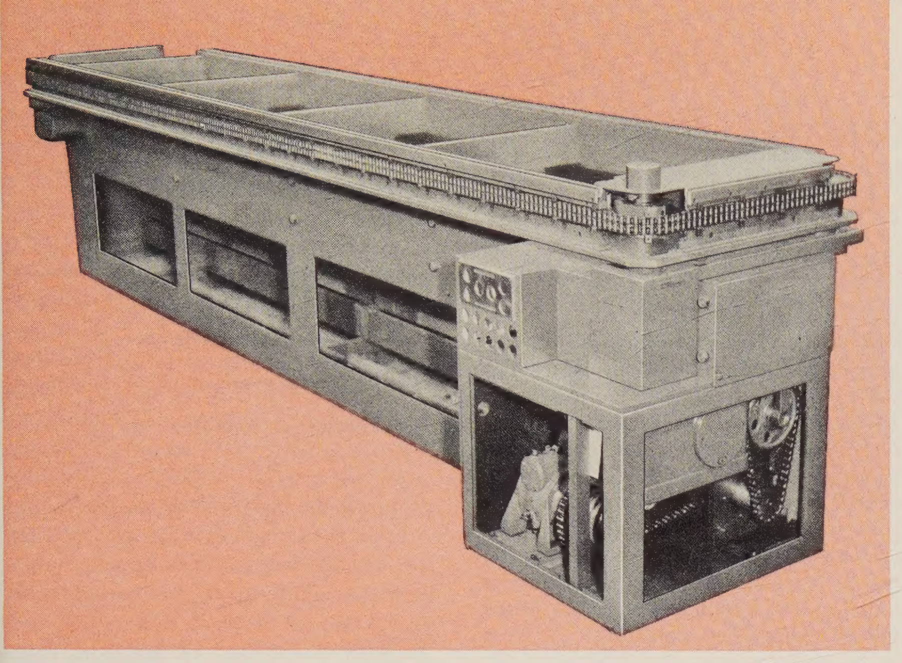


Fig. 7—The mechanism of the wide-track machine is clearly visible in this view of the base machine with panels removed. The indexed chain track is the heart of the in-line machine and is automatically controlled to traverse 5 in. per index time of 0.9 sec.

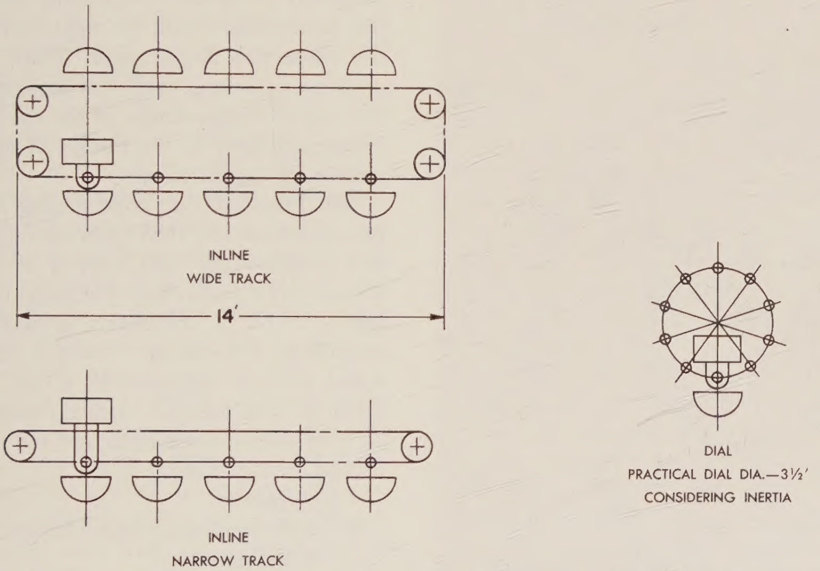


Fig. 8—Inertia factors limit the size of a dial assembly machine to a 3½-ft diameter, allotting little space for auxiliaries and operators (right). The in-line machine has a fixed index time of 0.9 sec with a chain travel of 5 in. per index. Note the increased operations permitted by this feature on the narrow- and wide-track in-line machines (left).

for the assembly to be located accurately with respect to the auxiliary equipment which is to perform work on the assembly. This can be done in the following ways:

- Lifting the part out of the nest for the operation
- Floating the work-holding station—the nest in the station—the assembly in the nest—the tool used in the auxiliary equipment—or
- Floating the auxiliary equipment itself.

Because of inertia factors, it has been found impractical to design a high speed indexing dial assembly machine larger than 3½ ft in diameter (Fig. 8). Here, the space for auxiliaries and operators is very limited, the 11-ft circumference permitting only the simplest of assemblies to be produced on this type of machine if a high production rate is to be maintained. The rapidity of the in-line machine's index and its 28 ft of available work space permit multiple operations which would require two or more dials. The construction cost is less and transfer from dial to dial is eliminated.

Summary

In the classroom laboratory, design may be taught on the best mechanical theories known. In industry, before any application of mechanical theory is attempted, careful consideration of a number of factors is made. The specifics of actual plant conditions and industrial economic considerations are not always available to the classroom laboratory. Because of such factors, industrial design in the plant often is founded on constructive compromises.

The common denominator of all technological progress is a better product at a lower price. In line with this industrial philosophy, the field of special assembly machinery has proved a rich one for exploration. While the original development costs may be high, they are justifiable from the economic standpoint—or they are not undertaken.

Although 50 of these in-line machines are used for a wide variety of applications at Delco-Remy, it should be remembered that, in relation to the total range of products produced, there are many assembly operations still performed by hand. Many studies are now being made and hand labor will be further reduced in the future by applying additional machines of the in-line type. As is so often the case with technological progress, labor deducted from one activity is absorbed by another, while still continuing to promote overall increasing productivity.

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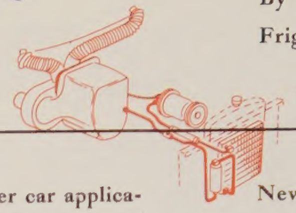
The Frigidaire Package-Type Air Conditioning Unit

By CURTIS P. KELLEY
Frigidaire Division



New car air conditioner provides year-around passenger comfort

A package-type cooling and heating unit designed specifically for passenger car application has been the goal of Frigidaire Division's air conditioning engineers for many years. Early automobile air conditioners consisted of several sub-assemblies which were installed in or on the car prior to the final assembly operation. The new Frigidaire package-type air conditioner which supplies both cooled and heated air for year-around passenger comfort consists of only three major components—compressor, evaporator, and condenser-receiver-dehydrator-filter assemblies. The three major components are completely fabricated, assembled, evacuated, charged, and tested at the Frigidaire factory prior to shipment to Chevrolet Motor Division. A specially designed crate functions as a locating jig in positioning the various parts of the air conditioner in the engine compartment. The new Frigidaire package-type air conditioner is unique in the line-up of automobile accessories designed especially for passenger comfort.

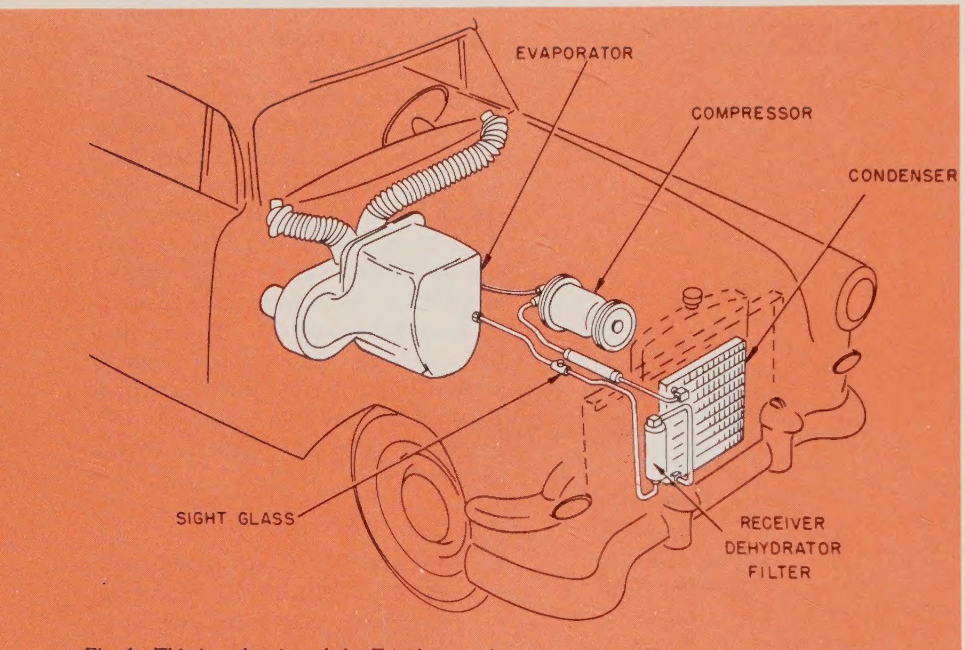


Fig. 1—This is a drawing of the Frigidaire package-type air conditioning unit for the 1955 Chevrolet showing the compressor, condenser, and evaporator as they are actually positioned on the car.

The first General Motors cars having factory-installed air conditioning systems were introduced by Buick, Cadillac,[1] and Oldsmobile on the 1953 models. These systems included the following major sub-assemblies:

- Compressor
- Condenser
- Receiver
- Dehydrator-filter
- Evaporator and blower assembly
- Refrigerant lines and fittings.

These sub-assemblies were installed in or on the various units of the car prior to being transferred to the final assembly line where necessary connections were made with the refrigerant lines to complete the system. For example: the compressor was mounted on the engine, the condenser on the radiator and fender sub-assembly, and the evaporator and blower assembly placed in the trunk compartment before these units arrived at the proper position on the assembly line. The refrigerant lines to be connected to the evaporator were also fastened to the frame of the car before dropping the body on the chassis.

From the foregoing it can be seen that the installation of the various components making up the air conditioning system created problems in handling and assembly operations. In addition, each system needed to be leak tested and then the entire air conditioning system had to be tested for proper functioning before the automobile could be approved by the Inspection Department. Thus, the need for a package-type unit located in the engine compartment of the car was recognized early in the history of automotive air conditioning.

The Frigidaire air conditioning unit introduced on the 1955 Chevrolet is the first package-type unit offered by the automotive industry. Package-type means that it is completely fabricated, assembled, evacuated, charged, and tested prior to shipment to a GM car Division. The complete package consists of three major components and the connecting flexible hose (Fig. 1):

- Compressor
- Condenser-receiver-dehydrator-filter assembly
- Evaporator.

Several factors which permitted the use of a packaged unit are:

(a) The use of cowl-type ventilation made it possible to bring outside air into a front-mounted evaporator without the use of expensive ducts.

(b) The development of flexible hose for use with Freon 12 made it possible to replace the copper refrigerant lines used on earlier systems, providing the necessary flexibility between the major air conditioning components.

(c) The combination of several components into a single assembly, such as the condenser and the receiver-dehydrator-filter assembly.

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[1] Owen, Webster J., "Development of the Cadillac Air Conditioner," General Motors Engineering Journal Vol. 1, No. 1 (June-July 1953), pp. 44-9.

(d) The development of a thin condenser which permitted easy installation between the radiator and grille.

The desirability of combining heating and summer air conditioning into a single unit was also recognized early in the development of the packaged system for the 1955 Chevrolet. This feature was accomplished by adding a hot water coil to the downstream face of the evaporator or cooling coil, thus providing both heating and cooling in a single housing.

Major Sub-Assemblies

Compressor and Clutch Assembly

The compressor is of the five-cylinder axial type and has a displacement of 9.28 cu in. per revolution. The main advantages of the axial type over other types of compressors used for automotive air conditioning are its small size and light weight (Fig. 2).

The clutch is of the friction type actuated by an internal solenoid positioned in the seal housing which is part of the compressor assembly. The clutch plates are located inside the pulley.

The clutch is operated by the internal solenoid which pulls the rear clutch plate into frictional contact with the clutch cover when energized. The initial frictional contact rotates the rear clutch plate relative to the front clutch plate, forcing the actuating balls up the cam surfaces so as to wedge the clutch plates apart and into frictional driving contact with both the pulley and clutch cover. At the same time, the clutch spring is compressed and since the front clutch plate is splined to the compressor shaft the pulley now drives the compressor shaft. When the solenoid is de-energized, the spring pushes the rear clutch plate toward the front clutch plate, thus disengaging the clutch. The pulley then rotates freely on the sealed ball bearing mounted on the compressor shaft.

Condenser and Receiver-Dehydrator-Filter Assembly

Even though the condenser and the receiver-dehydrator-filter assembly (Fig. 3) is actually a single unit when the packaged system is installed on the automobile, it is described herein as two separate parts.

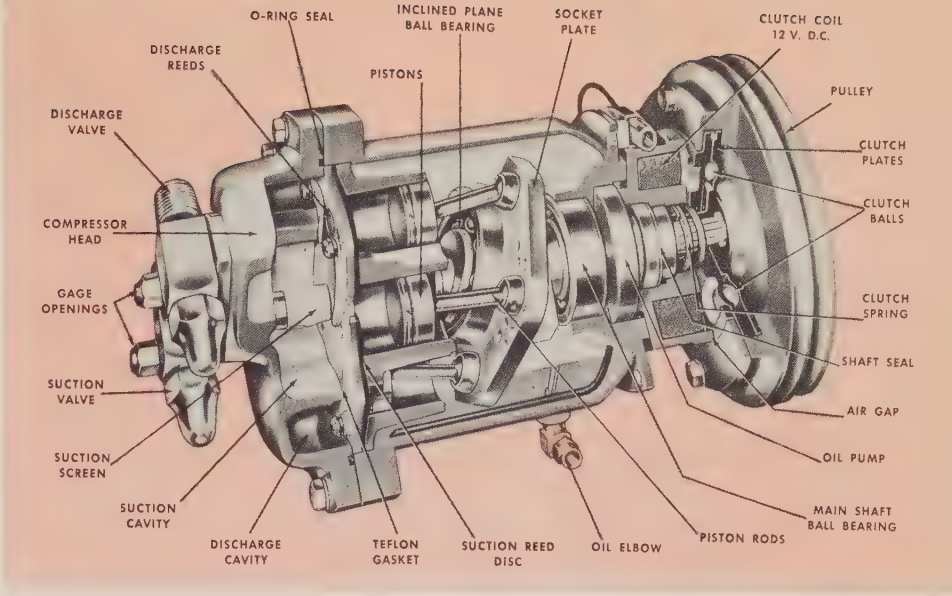


Fig. 2—This is a cutaway view of a five-cylinder axial-type compressor having a displacement of 9.28 cu in. per revolution. Its advantages over other types of automotive air conditioners are its small size and light weight.

The condenser is of all-steel construction having ten $\frac{3}{16}$-in. diameter tubes in parallel, grouped in two rows of five tubes each. The two rows are formed in a serpentine shape to reduce the number of joints to a minimum. Corrugated fins are stacked between the rows of tubing. The fin and tubing assembly, along with the mounting brackets, is copper brazed as a unit for good thermal contact and rigid construction. The condenser has adequate protection for resistance to corrosion. Large frontal area and minimum thickness offer little restriction to air entering the radiator at all driving conditions.

The receiver-dehydrator-filter assembly is unique in design in that it combines two components used on earlier systems into a single assembly. The receiver on previous automotive air conditioning systems was a simple tank which assured a solid liquid column at the expansion valve, regardless of the load conditions on the evaporator. The receiver on the Frigidaire packaged system has the filter screens and drying agent housed in the receiver shell, thus eliminating the dehydrator shell and fittings.

The condenser and receiver-dehydrator-filter assembly includes a third part which was handled separately on the original Frigidaire air conditioning units. This is the liquid refrigerant line from the condenser to receiver which, by being included in the brazed assembly, eliminates the connector and flare joint used at the condenser outlet on the original models.

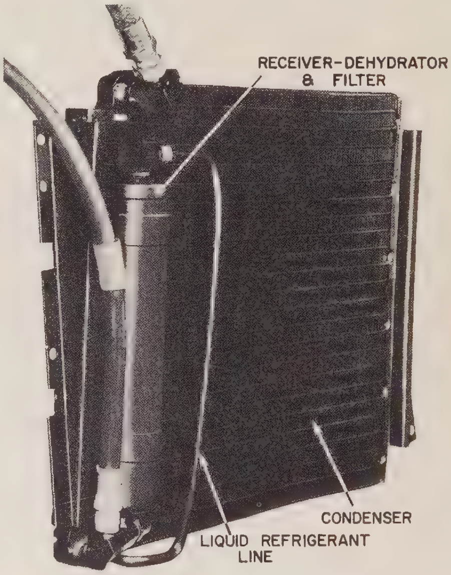
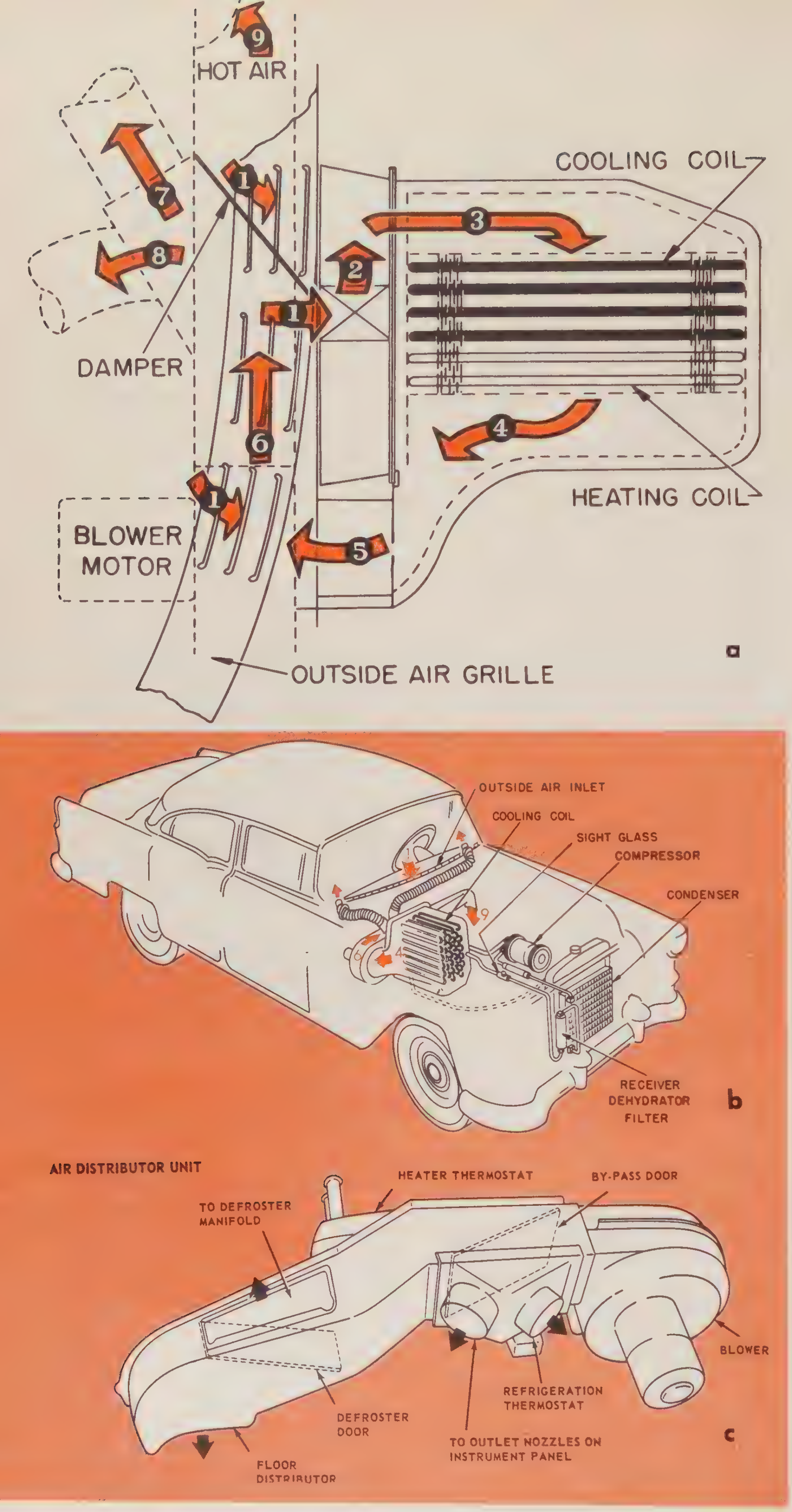


Fig. 3—The condenser and receiver-dehydrator-filter assembly is unique in that it combines two components used on earlier car air conditioning systems into a single, compact assembly.

The receiver-dehydrator-filter assembly is fastened to the condenser mounting bracket by means of two screw clamps. This permits easy replacement if necessary.

Evaporator and Heater Assembly

As stated before, the desirability of combining heating and summer air conditioning in a single unit was recognized early in the development of automotive air conditioning, since it would permit year-around use of a single blower and motor. Studies on the 1955 Chevrolet showed that it would be possible to make



minor changes in the standard heater arrangement without sacrificing performance or space inside the car. This was accomplished by making the following changes on the automobile:

(a) The blower and motor were moved inside the passenger space.

(b) The distribution duct was redesigned to eliminate the heater core housing, a regular heater damper was used to direct heated or cooled air to either the heater discharge or to the defroster nozzles, and another damper was added to direct cooled or heated air to the discharge nozzles in the dash or to the second damper (splitter).

(c) The heater core was eliminated from inside the passenger space and replaced by a Frigidaire core incorporated as an integral part of the packaged air conditioning system under the hood.

The fact that the 1955 Chevrolet would have cowl-type ventilation made it desirable to have the cooling coil as well as the heating core in front of the firewall. Since both outside and recirculated air are necessary for maximum overall comfort in the car, it was logical that openings be made in the ventilation duct and firewall for these purposes. These openings would also require dampers or air valves to control the air flow so Chevrolet engineers added an adapter for housing these parts (Figs. 4a, b, and c).

Both the cooling coil and the heating coil are made from individual finned tubing which is the type used by approxi-

Fig. 4—In Figs. 4a and b, outside air enters the cowl ventilation grille (arrow 1), passes into the adapter through a horizontal slot cut in the firewall side of the ventilation duct where a diagonal baffle changes the direction of flow from horizontal to vertical (arrow 2). The air then enters the cooling and heating coil housing through a vertical opening (arrow 3) where it passes over the coils. After being cooled or heated, the air (arrows 4 and 5) is fed to the blower housing located inside the car. The blower discharges the air into the distributing duct (arrow 6) where it is directed to either the discharge nozzles (arrows 7 and 8) or to the opening in the end of the distribution duct (arrow 9), or both, by manipulating the damper. The damper is shown directing air to the discharge nozzles in the instrument panel. For defrosting and floor distribution, the damper closes off the two ducts leading to the discharge nozzles and the air travels straight through the distribution duct to the floor distributor opening (4c).

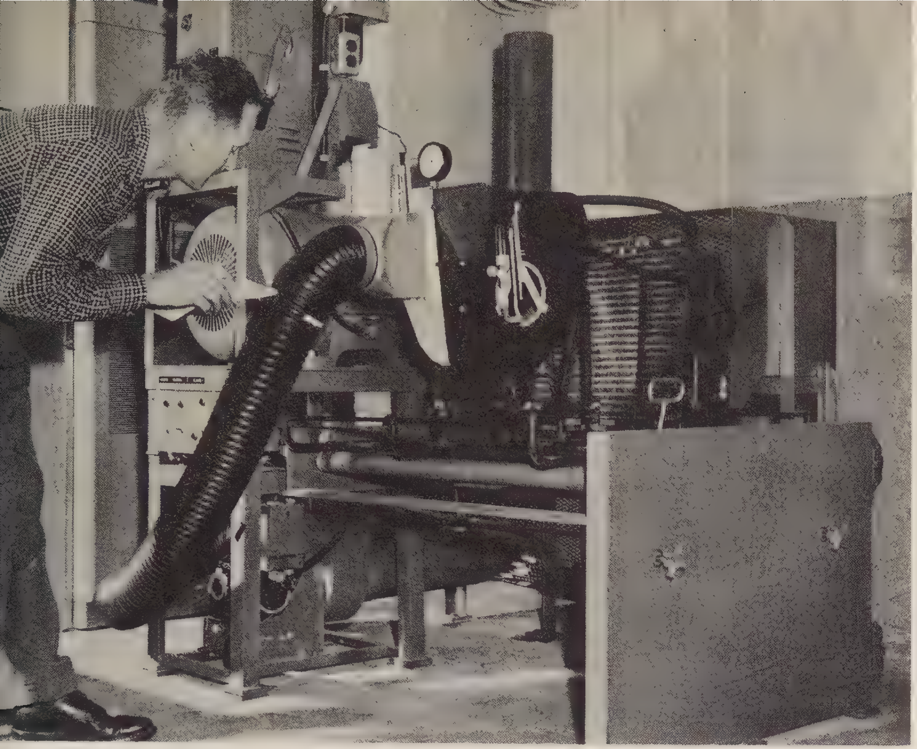


Fig. 5—A functional test is conducted in a humidity- and temperature-controlled room. The air conditioning unit and processing rack are placed on a test stand equipped with an electric motor for driving the compressor and blowers to furnish air for both the evaporator and condenser. The compressor is operated at approximately 1,750 rpm (40 mph equivalent), the air to the evaporator is maintained at 150 cfm, and the air to the condenser is controlled to give a condensing pressure of 175 psi. At the end of 15-min operation the temperatures of the inlet and outlet air to the evaporator as well as evaporator and condenser Freon 12 pressures are recorded. These must fall within limits set up in process specifications which were established by thoroughly testing a unit on an automobile in a wind tunnel and on the road. The operation of the clutch is also checked during the final tests by interrupting the electrical supply to the actuating coil described previously. This test is important since the temperature inside the car is controlled by cycling the clutch through a thermostat which is described in the text.

mately 50 per cent of the manufacturers of room air conditioning units at the present time. The coils consist of round- or button-type fins secured on a continuous tube. The fins are omitted where the tubing is to be bent to form return bends at the ends of each pass. Fig. 4a shows four passes of tubing for the cooling coil and two for the heater coil. The individual passes in both the cooling and heating coils are connected in parallel by means of manifolds to reduce pressure drop and to insure good distribution of refrigerant and antifreeze, respectively.

The manifolds on the heater coil have stub tubes leading to the outside of the evaporator housing to simplify making water hose connections.

The expansion valve for controlling the flow of liquid refrigerant to the evaporator cooling coil is located in the space between the face of the coil and the evaporator housing on the inlet air side. A removable cover is provided in the side of the evaporator housing for adjusting or servicing the expansion valve.

Unit Assembly

The assembly of the unit is accomplished by placing the individual components on a processing rack and connecting the refrigerant hose to the fittings on the compressor, condenser, and evaporator. The components are positioned on the rack in the same relationship to each other as they are in the automobile so as to prevent undue strains or twists in the refrigerant hose when the unit is installed in the car.

Leak Test, Evacuation, and Charging

The completed assembly is evacuated, charged with a mixture of Freon 12 and nitrogen, and leak tested. The unit is then discharged and evacuated to an absolute pressure within 3 mm mercury for at least 45 min. The oil and refrigerant are then charged into the unit with automatic equipment which accurately measures the amount of each. The oil charge is accurate within ±1 oz and the Freon 12 within ±0.03 lb. The charging equipment is also designed to make it impossible to charge the unit if the initial absolute pressure exceeds 9 mm of mercury. Following the charging operation the unit is given a functional test in a humidity- and temperature-controlled room (Fig. 5).

Packaging

Packaging the unit for shipment to the various Chevrolet assembly plants is important. Considerable study was given to the design of the shipping crate for the packaged air conditioning system and an appreciable amount of work was done in collaboration with Chevrolet to simplify handling the unit during the installation in the car. The crated unit (front section removed) is shown in Fig. 6.

Transfer of the unit from the processing rack to the shipping crate is accomplished by fastening the compressor and evaporator to the base of the crate and the condenser to the top before removing these assemblies from the processing rack. The base and top are then turned over as the assemblies are removed from the processing rack and the four sides of the crate nailed in place.

Installation in Car

In preparing the air conditioning unit for installation in the automobile the shipping crate is turned upside down so as to have both the evaporator and compressor assemblies suspended from the base. The base is supported by mechanical handling equipment while the sides of the crate are removed. The condenser assembly is then unbolted from the top of the crate and suspended from the base by means of a bracket and hooks (Fig. 7).

Controls

In addition to the standard heater and defroster controls the following controls are necessary for the air conditioning unit:

- Thermostatic switch for maintaining in-car temperature when cooling
- Switch for turning the unit on or off
- Duct valve control.

The thermostatic switch is operated by discharge air temperature at the blower outlet. This switch is mounted on the air distribution duct on the passenger side of the firewall with the thermobulb extending inside the duct. The setting of the switch is adjustable which enables the passengers to select the temperature at which the unit will operate for perfect comfort, regardless of outside temperatures.

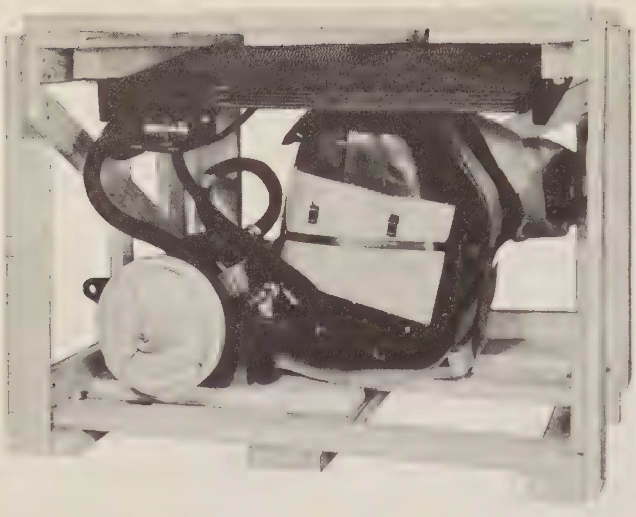


Fig. 6—The Frigidaire package-type air conditioning unit is shown here as it is crated for shipment. Note that both the compressor and evaporator assembly are mounted upside down for adequate support by the base of the crate while the condenser is fastened to the top to reduce the size of the crate to a minimum.

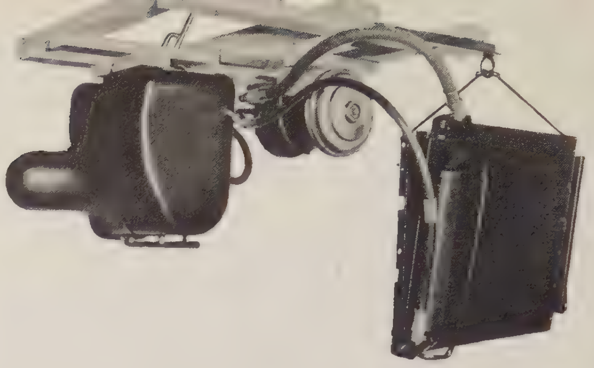


Fig. 7—When the sides of the shipping crate are broken away, the components of the air conditioner are positioned on the base in the same relationship to each other as they are when installed in the automobile. The refrigerant charge is checked by means of one of the gage connections in the shut-off valves on the compressor, and all hose connections are leak tested. This eliminates the possibility of a discharged unit being installed in the automobile and having to be replaced. The complete assembly is then positioned over the automobile and lowered so that all the components are in approximately actual mounting position. The condenser assembly is removed from the hangers and bolted in place. The U-bolt supporting the compressor assembly to the crate base is removed, the auxiliary brackets and supports assembled, and the compressor fastened to the mounting bracket on the engine by a single pivot bolt. The base of the shipping crate is then manipulated so as to engage the supporting studs, in the back plate of the evaporator, with the keyhole-shaped slots in the adapter. The banding strap holding the evaporator to the crate base is then removed. The evaporator assembly is supported by these studs until a V-shaped yoke is assembled over the flange of both the evaporator and adapter and tightened to hold the evaporator assembly securely in place. This yoke also serves to make an airtight joint between the evaporator housing and the adapter. The remainder of the installation is a matter of connecting the heater hose, installing the belt, connecting the clutch-operating solenoid to the wiring harness, and connecting the air outlet duct of the evaporator housing to the blower inlet.

The switch cycles the compressor to maintain comfort conditions; the 1955 Chevrolet is one of the first cars having this feature. Practically all residential comfort conditioning is controlled by cycling the compressor. This was made possible for automobile comfort conditioning by the development of the friction-type clutch described earlier.

The switch for the air conditioning unit is included as part of the control assembly used for the regular heater and defroster units. Chevrolet added a single lever which serves as the switch in the first part of its travel and as the adjustment for the thermostatic switch through the remainder of its travel.

The duct valve control operates the valve inside the air distribution duct to direct air to either the heater air valve or the nozzles in the dash, or both.

Final Test

As stated before, one of the advantages of the package-type air conditioning unit is the simplicity of the final test. First the engine is run for several minutes at low idle with the compressor clutch engaged. This establishes normal refrigerant distribution throughout the system and clears the compressor of any abnormal amount of refrigerant which may have collected during shipment. The thermostat is then set in the coldest position, the blower is set at high speed, and the damper is adjusted for maximum recirculated air. The engine is then run for about five minutes and when the compressor is cut out by the thermostat the temperatures of discharge air and the recirculated air are recorded. These must fall within test limits.

The controls are then adjusted to the heating cycle and the temperature of the discharge air checked.

Performance

Numerous tests have been run on experimental cars to check the performance of the air conditioning unit and the heater. These include road tests throughout the Southwest and at the General Motors Desert Proving Ground, Mesa, Arizona, as well as wind-tunnel tests in the laboratories. The unit maintained in-car temperatures in the low 80's during 115° ambients at the Desert Proving Ground and in the middle 70's with 100° ambients in road and wind tunnel tests.

The capacity of the heater is comparable with that of the regular car heater.

Summary

Careful studies of the design of early units for automotive air conditioning pointed out that standard refrigeration, air conditioning, and heating practices should be followed on future designs as nearly as possible; that is, the unit should be as simple and compact as possible and it should be assembled, processed, and functional tested prior to installation in a car. Also, the cost would be reduced considerably if the same distribution ducts and blower could be used for both heating and cooling.

The air conditioning system for the 1955 Chevrolet was designed with these criteria in mind. Instead of some six components which had to be located and mounted independently of each other and then connected by approximately ten sections of copper tubing, the package-type unit has three components connected by three lengths of flexible synthetic hose.

The air distribution system consists of a main duct with take-offs for connecting the discharge nozzles located at either end of the dash used for cooled air and to the transitions behind the instrument panel for defrost air and heater discharge. Dampers are provided for regulating the amount of outside and recirculated air. The same blower and motor are used for both heating and cooling.

The controls are also designed into a single group since the dampers and temperature regulators are so closely related and must be adjusted when changing from a cooling to a heating cycle.

Solving the Thermal and Structural Problems in Radiator Design for Automotive Cooling Systems

By HAROLD A. REYNOLDS
Harrison Radiator
Division

A few of the engineer's problems:
heat transfer, strength, space,
volume production, quality

The purpose of a radiator in an automotive engine cooling system is to dissipate the excess heat developed by combustion of the air-fuel mixture within an engine's cylinders. To efficiently carry out its function, the radiator's core section must be carefully designed to afford the maximum heat-transfer surface which will be compatible with accepted quality and manufacturing cost. To meet the cooling requirements of modern automotive engines, two major types of core design are utilized—cellular and tubular. There are many factors which the engineer must consider when specifying the type of core design to be used and the core surface-area required to meet the engine cooling specifications. Limitations imposed by styling, space availability, or type of operating condition require compromises to be made during a radiator's early design stages. Additional factors are encountered during a radiator's testing program which must be compensated for to maintain the required performance characteristics. The correct interpretation and analysis of all important factors influencing the overall design of an automotive radiator require sound engineering judgment if the radiator is to fulfill its intended purpose effectively.

THERE are three major factors which must be considered by an engineer when designing a radiator for passenger car or truck application:

- Thermal capacity required to satisfy engine cooling requirements
- Structural strength required to withstand a reasonable amount of stress and strain without permanent failure
- Best overall design which will be compatible with accepted quality and manufacturing cost.

Each of the three major factors may be modified or compromised to some extent to meet specific operating conditions. The final radiator design, however, must reflect the most efficient combination of the three.

The operating conditions under which a radiator must function efficiently when used for either a passenger car or truck application establish a basis for design. Passenger cars must be provided with a radiator which will have ample thermal capacity to satisfy engine cooling requirements at all car speeds under full throttle conditions. The *thermal output*, however, of the passenger car radiator, or the amount of heat it removes from the engine coolant, is aided considerably by the air flow through the radiator resulting from the velocity of the car's forward motion. This is a factor which has an important bearing on the radiator's heat-transfer surface necessary to give the required thermal capacity. Radiator requirements for trucks, on the other hand, are such that the engine must be adequately cooled at maximum engine torque while the truck is stationary. The air volume required for the heat-transfer process in this instance is supplied solely by the engine-driven cooling system fan.

Radiator Core Design and Construction

Combustion of the air-fuel mixture within an engine's cylinders develops exceedingly high temperatures. After producing useful mechanical work, the remaining heat must be carried away by the engine cooling system, exhaust system, and the lubricating oil.

The engine cooling system removes approximately one-third of the heat created during the combustion process by the principle of circulating a liquid, usually water, through jackets which surround the cylinders, cylinder head, and valves. The circulating liquid transfers the heat absorbed to the radiator where it is then dissipated to atmospheric air. The radiator's ability to dissipate efficiently the heat rejected by the engine to the circulating coolant depends on the design of its heat-radiating, or *core*, section which is composed of numerous air cells and water passages.

Two basic types of radiator core designs are currently in use—cellular and tubular. Each design is especially adapted to meet a specific type of operating condition. A radiator core designed to meet the cooling requirements of one engine might not be satisfactory for another.

Cellular Core

In the cellular type of radiator-core design, water tubes and air cells are formed to a full core depth from thin-ribbon copper sheets (Fig. 1). The outer edges of the water-tube sheets are crimped or corrugated at intervals corresponding to the vertical air-cell spacing desired. Between the corrugations the metal surface is depressed to form a water course. These depressions are interrupted at the center to provide a narrow knee for structural support and to divide the water course into two separate passages.

The water-tube sheet for a cellular core is slightly longer than double the core height and is folded square at both ends. This serves to form an envelope which encloses the air center and provides a flat surface for attachment to the top and bottom water tanks of the radiator. One end of the tube sheet is overlapped slightly to permit a liquid seal when the core is bonded in a solder dip.

Cellular core water-tube sheets are usually made of high-grade electrolytic copper, although some tube sheets are occasionally made from a rich low-brass composition of 85 per cent copper and 15 per cent zinc which allows greater ease in fabrication for a particular water-tube sheet design.

Air-center corrugations are formed from a serpentine-shaped ribbon of stock to a size required to provide a specified horizontal water-tube sheet spacing. The frequency of the air-center corrugations

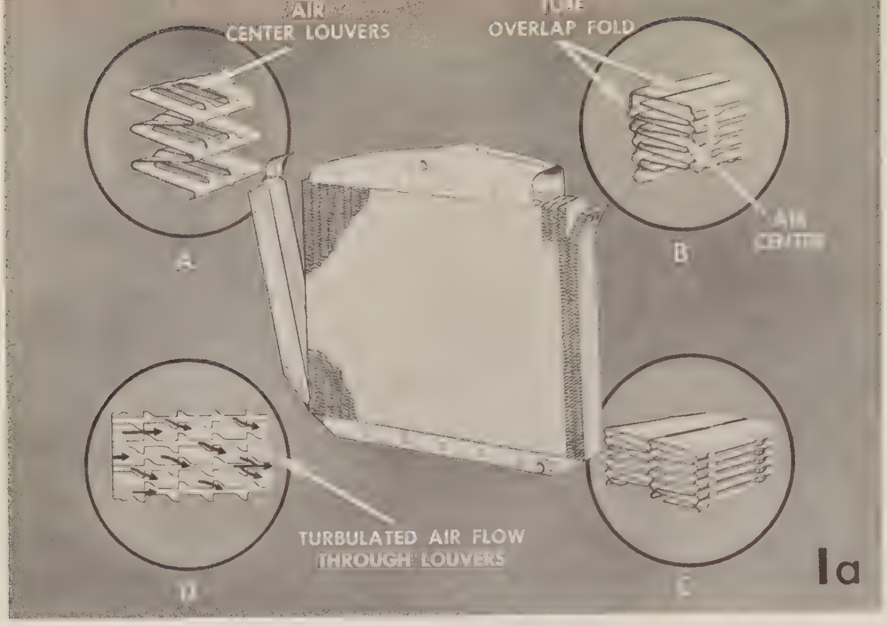


Fig. 1—Fig. 1a illustrates the cellular type of radiator core which is composed of a side-by-side series of individual water-tube and air-center envelope assemblies. Each assembly is made of air-center corrugations fitted inside of a water-tube sheet. Each water-tube sheet is slightly longer than double the core height and is folded square at both ends to form an envelope which encloses the air-center corrugations and provides a flat surface for attachment to the radiator's top and bottom water tanks. The air-center corrugations, formed from a serpentine-shaped ribbon of electrolytic copper, have louvers *A* which cause turbulence in the air stream entering the core *D*. One end of the water-tube sheet is slightly overlapped *B* to provide a liquid seal when the core is bonded in a solder dip. In Fig. 1b, an enlargement of *C* shown in Fig. 1a, the outer edges of the water-tube sheet are crimped or corrugated at intervals corresponding to the vertical air-cell spacing desired. Between the corrugations the metal surface is depressed to form a water course. These depressions are interrupted at the center to provide a narrow knee for structural support and to divide the water course into two separate passages.

determines the vertical air-cell spacing. Because of its distinctly superior heat-transfer qualities, electrolytic copper is used almost exclusively for cellular air-center corrugations.

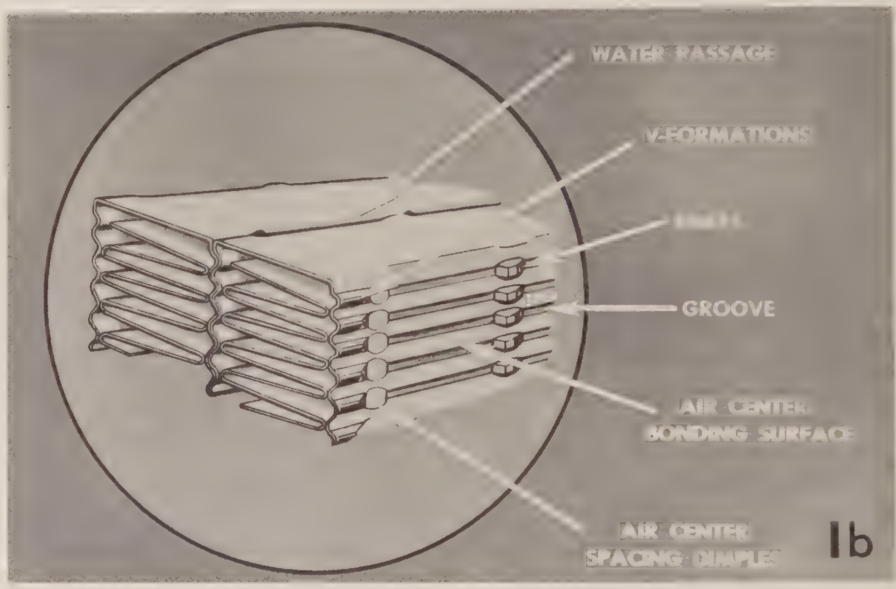
The air-center corrugations fit inside of the water-tube sheet to form one water-tube and air-center envelope assembly or *cell*. A series of such cells, placed side by side until a desired width is obtained, forms a complete core.

The overall core assembly is thermally and mechanically bonded together with a tin-lead solder. Each core face is alternately preheated and then immersed to a shallow depth—first in soldering flux and then in molten solder. The capillary action resulting from the rapid vaporization of the soldering flux in contact with the preheated core metal causes the solder to flow to all wet surfaces. This action insures a continuous bond for the full length of the water-tube and air-center contact surfaces.

Tubular Core

The tubular type of radiator core is available in two different designs—the *tube and flat fin* and *tube and corrugated fin*.

Tubular cores provide a design which may be adjusted to suit almost any operating condition by selecting the proper material gage for water tubes and water-tube headers without seriously affecting the overall assembly. The water tubes are usually a flattened oval shape and lockseamed at one edge. For extremely high pressure units—100 psi or higher—where lubricating or converter oil is to be cooled, round tubes are specified to eliminate wall deflection.



In the tube and flat fin type of tubular core design, individual fins are stacked in a frame and are spaced at a predetermined vertical distance from each other (Fig. 2). The fins have flanged slots through which vertical water tubes are inserted. The bond of the water tube to the fin is accomplished by a baking operation during which a heavy film of tin-lead solder, placed on the water tube during its fabrication, melts and fuses to each fin around the flanged tube slots. Each fin is bonded thermally and mechanically to the water tube which is inserted through it and the bond provides the necessary attachment for both heat-transfer surface and structural resistance to internal pressure, shock, and vibration.

With the tube and flat fin type of tubular core, an upper and lower header is required to facilitate attachment of the core to the upper and lower tanks of the radiator. Attachment of the water tubes to the headers is accomplished by either hand-sweating with a torch, by dipping in molten solder, or by utilizing a thin strip of solder foil which has been perforated to permit assembly over the water tubes. The solder foil contacts the external header surface and facilitates fusing of the header to the water tubes by means of a torch or furnace heat.

The tube and corrugated fin type of tubular core is also known as the *tube and center* or the *tube and cellular core*. This type of core design uses water tubes identical or similar in shape to the water tubes of the tube and flat fin type core and air centers similar to those of the cellular type core (Fig. 3). Horizontally spaced between the water tubes are the air centers. The water tubes and the air centers are stacked alternately until the desired width of the core is attained. This type of core also requires top and bottom headers.

Cellular and Tubular Core Comparison

The cellular type of radiator core is easily adaptable to high-volume production and, as a result, makes it somewhat cheaper to manufacture than a tubular core. The almost perfect bond between the water tube and the air-cell surface plus the turbulence introduced in the cooling air streams by the design of the air centers result in a thermal efficiency per pound of cellular core metal superior to that of the tubular type of core design. Cellular radiator cores, also, are quite flexible as compared to the tubular design. This flexibility permits absorption of considerable road shock and vibration without excessive fracture. Field repairs and core replacement are accomplished with less difficulty and expense than similar operations on tubular cores on which the header sheets are not readily detachable. The flexibility of the cellular core, however, makes it susceptible to deflection and eventual failure when subjected to severe intermittent pressures. Cellular cores are ideally suited for many passenger car and light-truck applications and are currently used on the majority of these types of vehicles.

The tube and flat fin type of tubular core has been specified for many years for heavy-duty truck service and other installations where a rugged core element is desired. The somewhat higher manufacturing cost and lower thermal efficiency per pound of core metal for this core require that it seldom be specified unless the engine cooling system pressure is in excess of 7 psi or the type of service operation requires the structural strength provided by this design. The tube and flat fin core, with wide fin spacing specified, is widely used in industrial and agricultural applications, primarily to facilitate the removal of dirt, chaff, and other residue normally accumulated from these types of operations.

The primary purpose of the tube and corrugated fin type core is to combine the ruggedness and resistance to internal cooling system pressures associated with tube and flat fin type cores along with the superior thermal efficiency of cellular cores by utilizing cellular air centers. Actually, the results obtained indicate a minor compromise of both objectives but are sufficient to warrant consideration of the tube and corrugated fin core as an alternate for either the tube and flat fin or the cellular, particularly as there is a substantial economic advantage over the tube and flat fin and a somewhat smaller cost penalty over the cellular. In recent years, the tube and corrugated fin type core has become increasingly popular and has been specified as initial equipment to replace both the tube and flat fin and the cellular cores. It also is used quite extensively for service replacement of tube and flat fin cores, particularly as the tanks and fittings for either type are interchangeable.

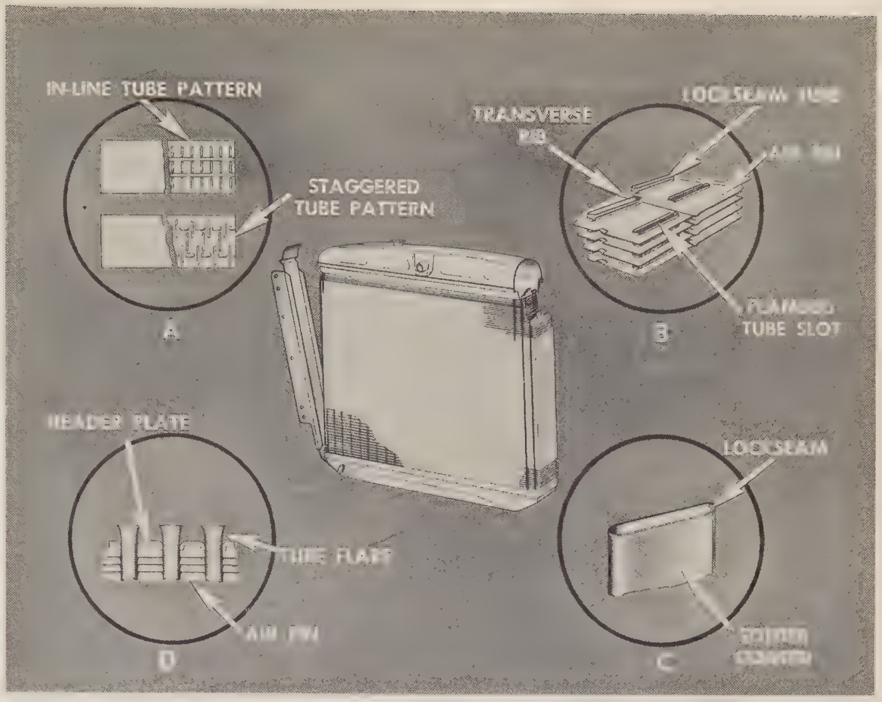


Fig. 2—The tube and fin type of radiator core is composed of a series of vertically spaced air fins having flanged slots through which water tubes are inserted. The slots are arranged to give either an in-line or staggered tube pattern *A*. Each air fin is formed with a transverse rib section *B* which provides added strength. The water tubes are oval in shape and lockseamed at one edge *C*. When all tubes have been inserted, the core is subjected to a baking operation during which solder melts and fuses each tube to each fin around the flanged tube slot. An upper and lower tube-header plate *D* is required to facilitate attachment of the core to the radiator's water tanks.

Factors Influencing Radiator Core Thermal Requirements

A factor to consider when determining the core surface-area for a specific radiator application is the cooling index required. *Cooling index* refers to the core-inlet air temperature at which the engine coolant boils when the vehicle travels at a certain speed at full throttle. For example, a cooling-index specification might state that the engine coolant will boil at a core-inlet air temperature of 96° F when the vehicle travels at a full throttle speed of 20 mph and at a core-inlet air temperature of 112° F at a full throttle speed of 80 mph.

The determination of the proper core surface-area to provide a specified cooling index should be a comparatively simple procedure, providing the values of the contributing major factors are known or can be estimated with reasonable accuracy from existing data of comparable equipment.

The major factors which influence the calculations pertaining to a core's surface-area requirements for a specific application are:

- Total heat to be dissipated
- Core-inlet air temperature
- Available air volume
- Rate of engine coolant circulation
- Engine coolant specification
- Maximum permissible engine-coolant temperature or operating pressure
- Core dissipation capacity at specified air and liquid flows and temperature differential.

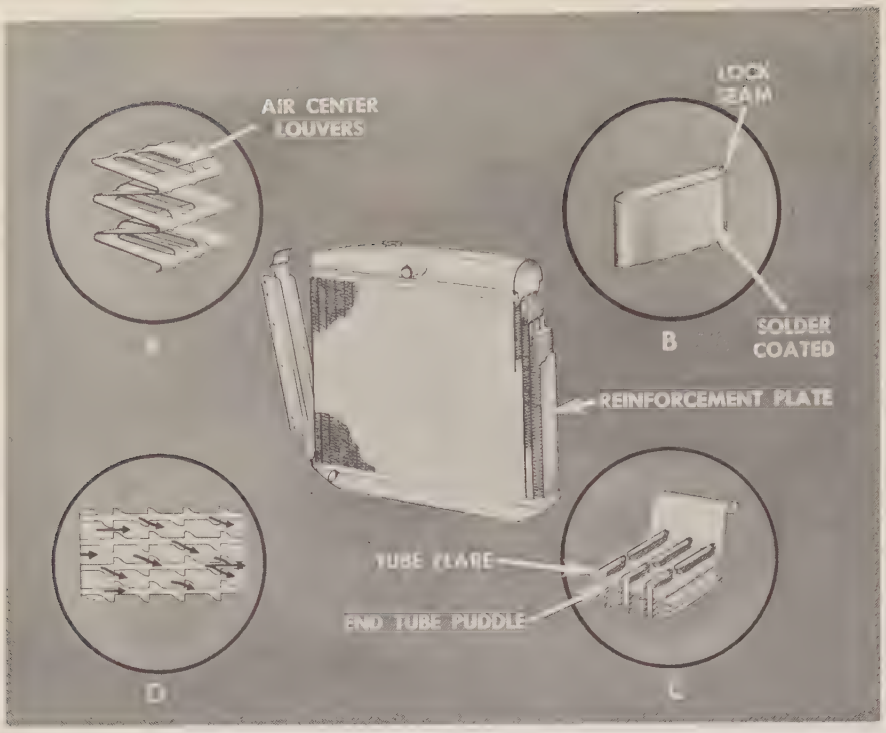


Fig. 3—The tube and center type of radiator core uses air-center corrugations, similar to those used for cellular type cores, having louvers *A* to introduce turbulence to air entering the core *D*. This type of core also uses water tubes, lockseamed at one edge *B*, similar to those used for tube and flat fin cores. The water tubes, flared at the top and bottom, and air-center corrugations are stacked alternately until the desired core width is obtained. The entire assembly is then subjected to a baking process during which a solder bond between the water tubes and air-center corrugations *C* is achieved. This type of core requires a top and bottom tube-header plate to facilitate attachment to the radiator's water tanks.

Total Heat to be Dissipated

The total heat absorbed by the engine coolant which must be dissipated by the radiator core is the sum of the engine's heat rejection plus the heat absorbed from such sources as automatic transmissions, torque converters, and lubricating oil which utilize the engine-coolant circuit for cooling purposes.

Engine heat rejection is commonly referred to as the number of Btu rejected to the coolant per minute under full throttle conditions at any given engine speed. Engine heat rejection values are usually available from manufacturers' laboratory tests or they may be calculated with reasonable accuracy on a Btu/bhp basis which may vary considerably, depending on the type and design of the engine to be cooled. Heat rejection values for contributing sources other than the engine also are available from manufacturers' laboratory tests or may be calculated from the weight of coolant flow and its temperature rise through the engine.

Modern high speed, overhead-valve, eight-cylinder engines have relatively low heat rejection per horsepower. This is because of their high-power efficiency resulting from high compression ratios and cylinder-head and manifold design. Lower heat rejection to the engine coolant also results because of the reduced flame-swept areas of the overhead-valve engine's short-stroke arrangement. Also, the traverse of the exhaust discharge reduces the amount of coolant temperature absorption from this source.

The large flame-swept area and longer exhaust discharge of L-head type engines are reflected in their higher heat rejection per horsepower. Table I shows an approximation of the heat rejection per horsepower at maximum power output of various types of engines.

Core-Inlet Air Temperature

The *core-inlet air temperature* usually refers to the maximum ambient atmospheric temperature at which the vehicle is to be operated. When calculating the cooling capacity of the radiator, consideration must be given to the influence such items as the refrigeration condenser mounted in front of the core on an air conditioned car or the radiator-grille configuration will have on the ambient air temperature entering the core.

Available Air Volume

For passenger-type vehicles and light delivery trucks, the available air volume is the sum of the air flow resulting from the cooling system fan plus that resulting from the forward motion of the vehicle. For heavy-duty trucks, which must be cooled under stationary conditions, only the cooling system fan air volume through the core can be considered as available.

Rate of Engine-Coolant Circulation

The rate of engine-coolant circulation is an important factor in the overall performance of the cooling system as it affects the velocity of the coolant through the engine's water jackets and radiator. As the velocity of the engine-coolant circulation is increased, its temperature drop through the core is reduced. This results in a greater mean temperature differential between the coolant and the air temperature entering the core, thereby improving the core's thermal output. Influence from this source, however, diminishes as higher circulation flows are attained. For example, there is considerably more improvement in a core's dissipation capacity by increasing the flow rate of the engine coolant from 20 gallons per minute to 30 gpm than by increasing it the same amount from 60 gpm to 70 gpm. Ordinarily, engine coolant rates of circulation which result in temperature drops through the core of 12° F to 15° at 1,000 rpm to 1,500 rpm and 9° F to 12° F at 3,000 rpm to 3,500 rpm under full throttle conditions are considered satisfactory.

Engine-Coolant Specification

Radiator cooling specifications are usually determined on the basis of water as the engine coolant. An aqueous solution of 50 per cent glycol and 50 per cent water, however, is sometimes specified. In such instances, the engineer must discount the radiator-core dissipation capacity 15 per cent because of the reduced specific heat of the aqueous solution of glycol and water.

Engine-Coolant Temperature or Cooling System Pressure Operation

Most modern engine cooling systems are designed for pressure operation varying from 4 psi to 15 psi. This is done for two reasons: (a) most of the water loss associated with atmospheric engine cooling systems is eliminated and (b) the boiling temperature of the engine coolant is increased 2.8° F per pound of pressure increase, permitting operation at higher engine-coolant outlet temperatures which results in a greater temperature differential between the air entering the core and the temperature of the coolant in the top radiator tank. This, in turn, improves the thermal capacity 1 per cent or 1° F for each additional degree of temperature differential.

ENGINE HEAT REJECTION AT MAXIMUM POWER OUTPUT

Type of Engine Design	Heat rejection per horsepower (Btu)
High Speed, High Compression, Overhead Valve	30 to 35
Conventional L-Head (passenger car)	40 to 50
L-Head, Low Speed, Low Compression (truck)	45 to 55
L-Head, Low Speed, Low Compression, Heavy Duty (truck or tractor)	50 to 65
Heavy-Duty Diesel Engine	35 to 40

Table I—Engine heat rejection, referred to as the number of Btu rejected to the engine coolant per minute under full throttle conditions at any given speed, varies considerably for each type and design of engine to be cooled.

Core Dissipation Capacity

Modern radiator cores have been developed to a high degree of thermal efficiency. Radiator manufacturers have accurate and reliable performance data obtained from laboratory heat dissipation tests under controlled conditions of air flow, coolant rate flow, and temperature differentials of coolant and core-inlet air which indicate the optimum heat dissipation capacity of various available core surfaces.

At Harrison Radiator Division, radiator core performance curves are usually plotted on a square-foot-of-core basis (Fig. 4). The performance curves indicate a specific core's capacity in Btu/min/100° F temperature differentials at variable rates of coolant and air flow and also the static resistance in the core resulting from air flow at various velocities. Performance characteristics of any size core of each type of surface can be readily determined for any pre-selected specification of air flow, coolant flow, and temperature differential.

The total thermal capacity of any core surface varies approximately in direct proportion to the relation of core frontal (core-surface) area. If the ratio of change is large, however, consideration should be given to the mean temperature difference of the coolant. The total capacity of a core also varies in direct proportion to the difference between the core-inlet air and top tank coolant temperatures, that is, 1 per cent or 1° F for each degree of temperature differential change.

As previously stated, the rate of engine coolant circulation introduces a third variable which must be considered in the evaluation of a core's thermal capacity.

Selection of Core Surface-Area

In selecting the proper core surface and radiator size for a specific installation, two factors must be considered:

- Maximum frontal area available
- Maximum engine operating temperature which is compatible with the type of installation proposed.

The maximum ambient air temperature in which the radiator will be required to function subtracted from the maximum engine coolant outlet temperature at the top tank indicates the maximum temperature differential available for cooling. The shallowest core depth and the widest air-cell spacing necessary to provide the required total heat dissipation in the available frontal area and differential would be the most economical and efficient selection. If this selection is inadequate for the total thermal capacity required, the next step would be to consider closer spaced air cells. If this is still not sufficient, a closer water-tube spacing which would increase the water-tube count should then be considered. An increase in core depth should only be considered as a last resort to provide the necessary thermal capacity, as it is the least efficient and most expensive selection.

As an example, tests have shown that a 50 per cent increase in core depth (from 2 in. to 3 in.) will increase the heat dissipation capacity only about 15 per cent, whereas a 100 per cent increase in core depth (from 2 in. to 4 in.) improves the dissipation capacity about 20 per cent for automotive applications. This is due primarily to the inability of the conventional disc-type engine cooling system fan to maintain the air flow against the increased static pressure through the core. In applications where positive air flow can be maintained, regardless of the higher static pressure resistance, deeper depth cores will show a corresponding increase in heat dissipation performance.

Radiator Structural Design

The overall size and relative location of a radiator with respect to other under-hood components are invariably controlled by the dimensional limitations of a specific installation. Such factors as the size and shape of a radiator's upper and lower coolant tanks, the diameter and location of inlet and outlet fittings, and the overflow drain also are influenced or dictated by the installation. The anchorage design depends largely upon the type and relative location of the mounting harness with respect to the radiator and other related parts.

Passenger Car Radiator Tank Capacity

The required liquid capacity of radiator top tanks has been a rather controversial subject among automotive engineers. Some prefer large tanks to provide extra reserve while others feel that this is unnecessary expense and not required in normal operation.

When engine cooling system pressure operation was first introduced, Harrison Radiator Division initiated the use of smaller capacity top tanks for two reasons: (a) under pressure conditions, coolant loss was minimized and the need for substantial reserve capacity was no longer essential for continuous operation and (b) large-capacity top tanks were subject to excessive wall deflection under pressure operation which resulted in numerous field failures at low mileage. It has been shown that smaller capacity top tanks substantially reduce the total unit force exerted on the tank-to-core joint and, when the tank overhang is symmetrically balanced with respect to the core faces, the destructive effort on this joint is further reduced.

Ordinarily, a simple method for establishing the minimum top tank capacity is to provide a capacity which is 15 per cent of the total engine cooling system capacity plus one quart. The 15 per cent allowance should adequately cover normal expansion throughout the operating temperature range of a 50 per cent glycol and 50 per cent water mixture, which has

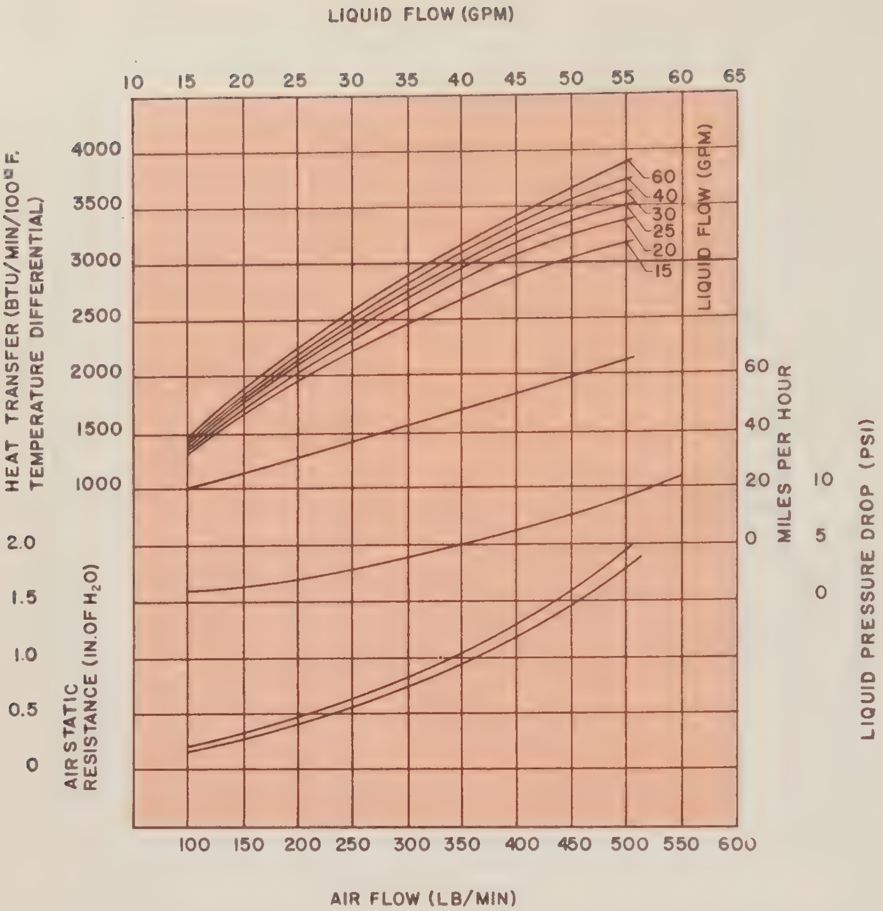


Fig. 4—This illustration represents a typical heat-transfer performance chart of a specific core surface and face area. A separate chart is required for each depth of core and density of cell structure. The performance chart indicates the optimum heat transfer (in Btu/min/100° F temperature differentials) between the entering coolant and ambient air, static resistance (in inches of water) to the air flow through the core, and the liquid pressure drop of the coolant through the core. These performance factors are plotted at variable air and liquid flows, expressed in lb/min and gpm, respectively. Standard air weight of 0.07651 lb/cu ft may be used to transpose lb/min to cfm.

an expansion somewhat greater than 100 per cent water, and an additional capacity of one quart should be sufficient reserve on pressure systems.

The bottom-tank capacity is relatively unimportant and it is usually controlled by the core depth and the minimum tank height necessary to accommodate the outlet fittings. Invariably, this combination provides ample section area to avoid any restriction to liquid flow.

Cellular Core Tank Design

When cellular cores are used for relatively low-pressure engine cooling systems the top tank is usually of a rectangular section. This type of tank section provides maximum liquid capacity in a minimum of space and simplifies the tooling and formation of underfold flanges necessary for attachment of the top tank to the cellular core section. The vertical walls of the rectangular top tank require heavy and frequently spaced ribbing to prevent excessive deflection under the intermittent pressure application encountered in normal operation.

Bottom tanks, as used on cellular cores, are drawn in an inverted hat-shaped section having out-turned flanges. The extended flanges provide the necessary surface for attachment to the core section. As in the case of the top tank, the vertical walls of the bottom tank also are ribbed to reduce deflection and to provide the necessary rigidity required in normal operation.

Tubular Core Tank Design

Inasmuch as tubular cores are usually specified for high-pressure engine cooling systems and are assembled to a header to which the core's water tubes are separately attached, underfold flanges are not required. Deflection of the top-tank walls is minimized by the use of a rounded top surface which results in a semicircular top-tank section. Vertical wall height is kept to a minimum and, if extension is necessary to provide sufficient liquid capacity, external ribs are utilized to reduce deflection.

The semicircular top-tank section also is incorporated in the bottom-tank design. The ends of the bottom tank, however, are squared to accommodate the outlet fittings and to provide the necessary flat surface for anchorage attachment.

Cellular and Tubular Radiator Core Fittings

Wherever space limitations permit, coolant inlet and outlet fittings are fabricated from seamless brass tubing or are drawn from sheet brass. Because of their relatively thin wall, tubular fittings provide the maximum flow area for any given external diameter and are much more economical to fabricate and process through assembly than cast fittings. Radiator hose-ends are beaded to facilitate liquid sealing and, in addition, reinforce the tube against handling damage. For these reasons, cast fittings are never specified unless dimensional limitations will not permit the use of tubular fittings or unless demountable flanged fittings are required to suit some specific application.

Final Radiator Design Procedure

The preceding discussion has outlined, in a general manner, the various considerations involved in developing the preliminary core surface requirements for a proposed radiator design based on optimum values for all heat-transfer surfaces. Unfortunately, the optimum value condition almost never prevails in automotive operation, due to uncontrollable variations in several influencing factors. For example, it is not unusual for the heat rejection of production engines of identical design and manufacture to vary as much as 10 per cent. Also, the volume of air circulated through the radiator core depends largely upon the design and relative location of the grille, capacity of the cooling system fan under prevailing static pressure conditions, and other similar items. The final selection of a core's surface-area, depth, and air-cell spacing necessary to provide a desired cooling-index specification must, therefore, be based on a complete analysis of test results obtained under the most severe operating conditions which will be encountered in actual service.

In anticipation of variations which invariably have a detrimental effect on the cooling index, it is considered good practice to first determine the minimum core surface-area required with the widest air-cell spacing. This permits an approximate 10 per cent increase in radiator capacity without changing the physical overall size.

Serious consideration also must be given to design changes, rearrangement, or modifications of various components of the engine cooling system. In many instances, it is practical as well as economical to make minor changes on such components as the grille design, cooling system fan diameter, pitch, number of blades, drive ratio, fan-to-core clearance, type and design of fan shroud, and air seals. In many cases, minor revision in one or more of these areas will provide the necessary cooling-index specification with smaller or less dense core surface.

At Harrison Radiator Division, performance tests for radiator design analysis are conducted in a wind tunnel (Fig. 5). The wind tunnel, referred to as the "hot tunnel," is capable of producing a maximum air velocity of 125 mph and a maximum temperature of 125° F. A chassis dynamometer loads the engine which the radiator under test must cool and provides a means for controlled full throttle car speeds ranging from 30 mph to 80 mph. Core frontal air velocity is adjusted to correspond to various vehicle speeds and is indicated on specially designed measuring instruments. Top tank, bottom tank, tunnel air, fuel, and lubricating oil temperatures are indicated either on accurately calibrated distance thermometers or potentiometers. Engine rpm, mph, horsepower and torque-load, radiator and engine-block pressures also are indicated and recorded. From the data collected, the temperature drop of the coolant through the core, the air temperature rise, and eventually the cooling index can be determined. Faulty performance due to any of the controlling factors can be immediately identified and corrected for a re-run comparison. When analysis of the data is completed, the core surface selection may be finalized with considerable confidence in its eventual performance under actual operating conditions.

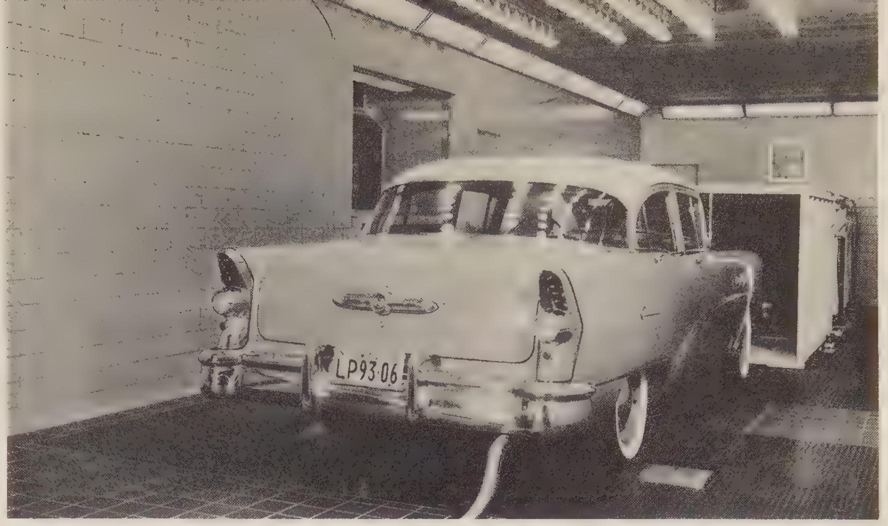


Fig. 5—Radiator design analysis performance tests are performed in a "hot tunnel" at Harrison Radiator Division. A chassis dynamometer loads the engine, which the radiator under test must cool, and provides full throttle car speeds ranging from 30 mph to 80 mph. The wind tunnel, located at the front end of the car, is capable of producing a maximum air velocity of 125 mph and controlled ambient air temperatures up to 125° F. A battery of infrared heat lamps provides the approximate equivalent of a sun load for air conditioning tests. The test is controlled from a control room (shown at the left) where special instrumentation is located to record all pertinent data.

A recommended radiator design procedure based on the preceding discussion is as follows:

(a) Completely analyze the radiator's required performance and installation specifications
(b) Make a preliminary selection of the type of core surface which will be best adapted to the specific installation
(c) Calculate the required core surface-area required to meet the engine cooling specifications
(d) Determine whether the available space limitations are sufficient to accommodate the required core surface-area
(e) If the space is inadequate, recalculate with alternate core surface-areas and select one which can be utilized
(f) Proceed with the preliminary overall radiator design
(g) Build a test radiator for an installation design check and conduct performance tests
(h) Make a complete analysis of installation and test results
(i) Revise radiator design, as required, to meet the specifications.

Summary

Someone once said, "The final result of any engineering development is invariably a compromise." Engineers will generally concede that this is unquestionably true as applied to the automobile and its component parts. Engineers, however, will also concur that the essence of good design depends upon the correct interpretation and analysis of all important factors which are based on reliable information and the relative influence of each compromise on the end result.

In a radiator design program, the need for consideration of compromises is usually established early enough in the preliminary design calculations. This situation prevails when the most effective use of a radiator core's cooling surface cannot be obtained because of limitations imposed by styling, location in the vehicle, space availability, and/or operating conditions.

Various other factors, not apparent in a radiator's preliminary design stages, are encountered during a test program and must be compensated for to maintain the required performance characteristics. Fan noise level or power absorption may be unacceptable when handling the prescribed amount of air flow through the radiator core and, when this is reduced, there may be a corresponding loss in the heat-transfer capacity of the radiator. Manufacturing cost, assembly, interchangeability, and serviceability also have an important bearing on the eventual design and efficiency of each specific radiator installation and, therefore, must be individually evaluated in the complete analysis of the engine cooling system performance.

A Method for the Simultaneous Quantitative Analysis of Carbon and Sulphur in Steel and Cast Iron

By **FRANKLIN L. RACINE**
GMC Truck & Coach
Division

An application of the feedback electronic control principle—employed to cut off the flow of an iodate solution used in determining the percentage of sulphur in cast iron or steel—has speeded up analyses at GMC Truck & Coach Division's Engineering Chemical Laboratory. GMC's chemists, experimenting with commercially available electronic instrumentation, have combined two conventional, manual, quantitative methods into a new laboratory setup for the simultaneous and nearly automatic determination of the carbon and sulphur content of steel and cast iron, using the same sample for both determinations. A principal feature of the new process is that the painstaking manual titrating step used in conventional sulphur analyses is made automatic by the use of an electronic titrimeter. The newly devised method is applied to the determination of the carbon and sulphur content in all ferrous metals. Well adapted to production methods, the entire process requires only 4 minutes, including 30 seconds to weigh the carbon result. Other advantages realized are greater accuracy, more dependability and flexibility, and economy.

Electronic feedback circuit combines and speeds up volumetric and gravimetric determinations

CAST iron contains, at the minimum, close to 2 per cent of carbon, along with some sulphur (about one-tenth of a per cent), and other impurities. Steel is defined as an alloy of iron and carbon, with the carbon content up to 1.7 per cent.

The limits on the percentages of the carbon and sulphur content in cast iron and steel depend on how these engineering materials are to be used. To illustrate, spring-type steel requires a high carbon content with up to 1 per cent carbon, while low carbon steels (a maximum of 0.25 per cent carbon), which are soft and, therefore, easily bent and formed, are used for automotive body panels, frames, and fenders. Steels with up to 0.50 per cent carbon content (medium carbon steels) are used for connecting rods, crankshafts, and camshafts. Cast iron is utilized for those automotive parts in which tensile strength is not a major requirement; for example, the engine cylinder block, manifolds, and piston rings are made of cast iron.

Regarding the effects of sulphur, a sulphur content of from 0.080 per cent to 0.150 per cent or more is desired in steels that are machined automatically at high speeds and for parts that are not subject to high impact stresses. However, for forging steels, a lower sulphur content is necessary because of this element's tendency to make cast iron and steel brittle at high temperatures.

New Method Developed

The conventional method of analyzing ferrous metals for their carbon-sulphur percentages involved two separate samples and two separate processes. The determination of carbon content in steel is made by the combustion of carbon to the gas carbon dioxide CO_2 and the absorption of this gas. The *iodometric method*—a chemical reaction which uses the blue color resulting from starch indicator in the presence of free iodine—is used to measure the amount of sulphur in steel and cast iron.

The new technique, as developed by the chemists in the Chemical Engineering Laboratory at GMC Truck & Coach Division, combines these two conventional methods, uses only one sample, and utilizes an electronic titrimeter to titrate the sulphur automatically.

Procedure of New Method

General Information

In this new setup, the furnace used for the combustion of the sample under analysis is a Globar heating element type of furnace which is heated to 2,600° F (Fig. 1). However, an induction furnace designed for sulphur analysis would serve also.

The glass sulphur chamber has a three-way stopcock at the bottom which serves as an entrance for the evolved gases leaving the furnace and as an exit for dumping the used solution. This chamber has a rubber stopper at the top through which the electrodes (spiraled platinum wire and calomel), titrating solution, and other solutions have their entrance. A perforated disc is inserted in the bottom of the chamber to break up the incoming gas stream. The flow of the gases produces enough turbulence to keep the system stirred well.

The solution in the sulphur chamber is composed of dilute hydrochloric acid HCl, starch, and potassium iodide KI which are allowed to run into the chamber from the bottles located on each side of the automatic burette. The result is a dilute acidic solution which is faintly blue. This blue tint is used to adjust the electronic system at the operation's beginning.

The electronic titrimeter is connected to the electrodes in the sulphur chamber. A 50-ml automatic burette, through which the titrating iodate solution drains into the sulphur chamber, is placed high enough to obtain the necessary head. The burette is arranged so that the incoming solution spurts directly onto the platinum electrode; this results in very close control since the immediate vicinity of the platinum wire is slightly overtitrated, causing a certain anticipation of the reaction's end point by the titrimeter. The stopcock regulating the flow of the iodate solution into the sulphur chamber is controlled by a solenoid device (not shown in Fig. 1).

Simultaneous Carbon and Sulphur Determinations

The initial steps in the carbon and sulphur determinations are:

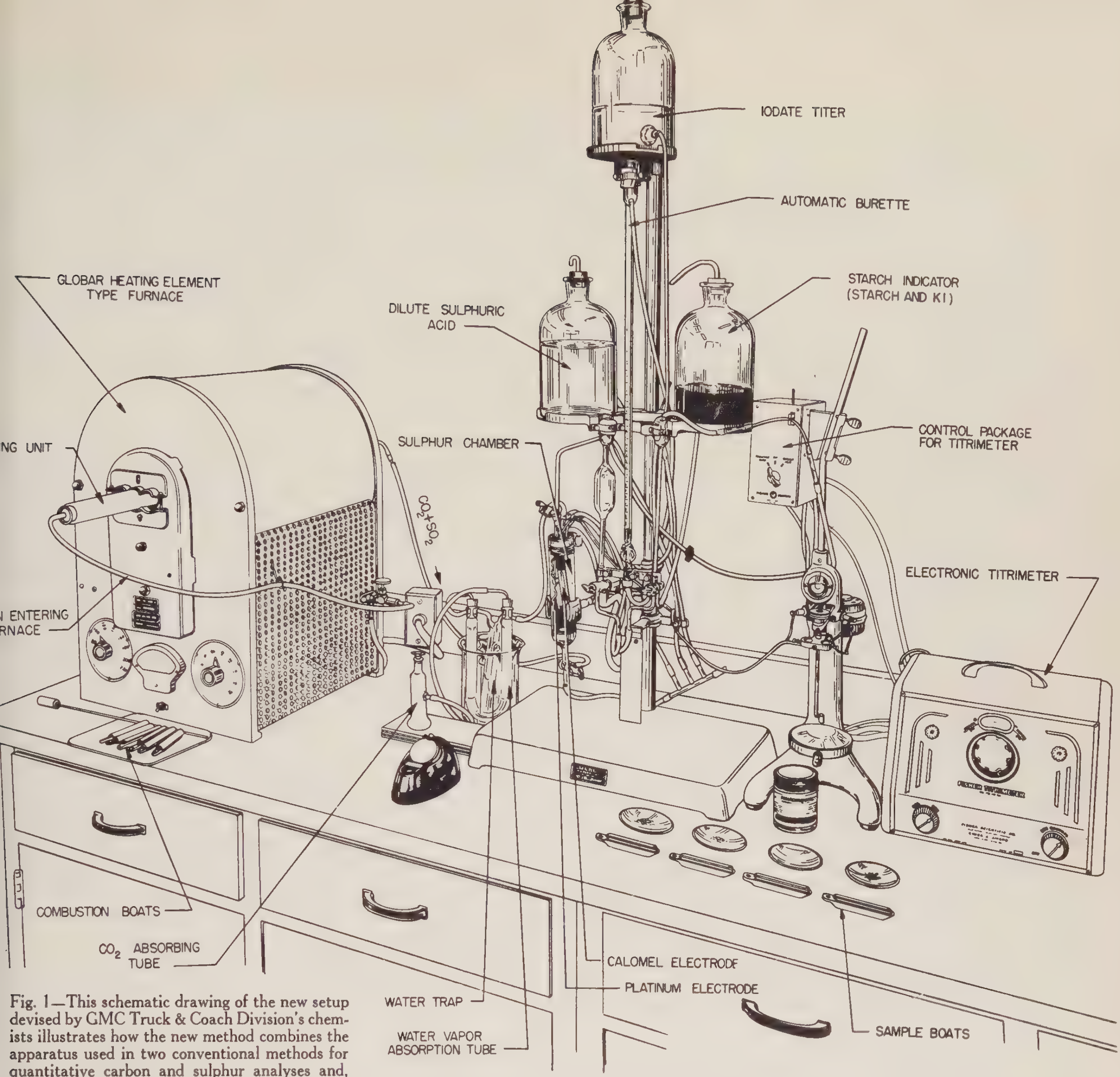


Fig. 1—This schematic drawing of the new setup devised by GMC Truck & Coach Division's chemists illustrates how the new method combines the apparatus used in two conventional methods for quantitative carbon and sulphur analyses and, in addition, utilizes an electronic titrimeter to automatically introduce the iodate solution. Using this new setup, a carbon-sulphur simultaneous determination requires only 4 min, including 30 sec to weigh the carbon result.

1. The sample is weighed, placed in a combustion boat, and the boat inserted in the heating unit of the furnace.
2. The sample receives a 30-sec preheat at 2,600° F.
3. Purified oxygen is passed over the sample at the rate of 1 liter per min.
4. The evolved gases, containing sulphur dioxide SO_2 and carbon dioxide CO_2, pass directly into the sulphur chamber where the sulphur dioxide is absorbed in the acidic solution present.

Carbon Analysis

Following the carbon dioxide from step 4 and using the carbon analysis flow diagram (Fig. 2):

5. The carbon dioxide flows out of the sulphur chamber through an opening in the rubber stopper and passes through (a) the water trap, a bubbling bottle containing concentrated sulphuric acid which eliminates most of the water carried over, (b) through a water vapor absorption tube containing an anhydrous calcium compound which takes out the traces of water vapor present in the gas and, finally, (c) is absorbed in the carbon dioxide absorbing tube which contains Ascarite. These three pieces of apparatus are known collectively as the "carbon train."
6. The carbon dioxide absorbing tube is weighed and this weight compared with the weight of the absorbing tube found before the analysis was started. The differ-

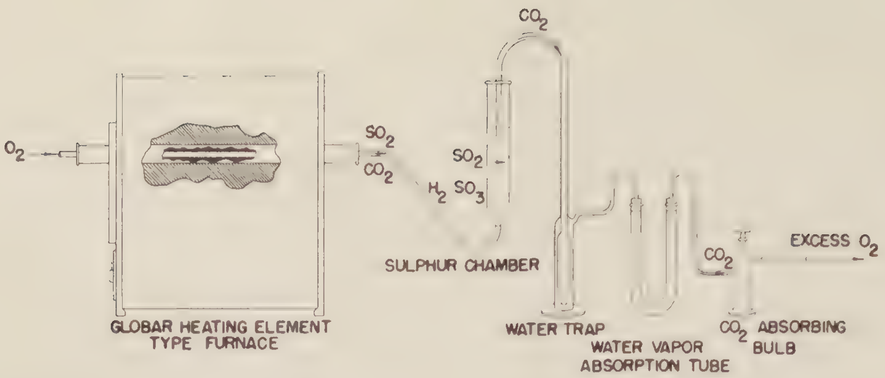


Fig. 2—This carbon-analysis flow diagram follows the carbon dioxide as it leaves the Globar heating element type furnace, enters and leaves the sulphur chamber, passes through the water trap and the water vapor absorption tube, and finally to the carbon dioxide absorbing tube. The gain in weight of the carbon dioxide absorbing tube is used in the ratio applied to find the percentage of carbon in the sample.

ence between these two values is the weight of carbon dioxide in the sample.

7. The percentage of carbon in the sample is determined by the ratio

$$\frac{\text{weight of carbon}}{\text{weight of carbon dioxide}} = \frac{\text{molecular weight of carbon}}{\text{molecular weight of carbon dioxide}}$$

and the formula

$$\text{per cent of carbon} = \frac{\text{weight of carbon}}{\text{weight of sample}} \times 100.$$

Sulphur Analysis

Meanwhile, following the sulphur dioxide from step 4,

8. The sulphur dioxide reacts with the acidic solution in the sulphur chamber (HCl, starch, and KI) to form sulphurous acid H_2SO_3.
9. As the sulphurous acid starts to form, the electronic titrimeter opens up the solenoid (stopcock controller) and the iodate solution enters the sulphur chamber. The titrimeter continues to allow the iodate solution to flow into the chamber as long as any sulphur dioxide gas, as sulphurous acid, is present. In the meantime, the iodate solution, entering the chamber through the burette, reacts with the newly formed sulphurous acid to form sulphuric acid.
10. At the moment all of the sulphurous acid has been changed to sulphuric acid (called the *stoichiometric point*), the predetermined electrical potential has been reached between the platinum and the calomel electrodes and the titrimeter actuates the solenoid which, in turn, closes the stopcock, cutting off the iodate solution flow.
11. The iodate solution concentration has been adjusted so that a simple burette reading will give the percentage of sulphur in the sample. The iodate solution, in this case, is called a *titer.*

While the iodometric method is used in this setup, the *acid-base* approach (titration of an acidic solution against a basic solution, using an indicator to determine the reaction's end point, for example, sulphuric acid titrated against sodium hydroxide with methyl orange as an indicator) is also possible. The incoming sulphur dioxide in this case is oxidized to sulphuric acid by having hydrogen peroxide present in the initial solutions.

Summary

The new technique, using an electronic titrimeter, offers many advantages over the conventional methods for the quantitative determination of carbon and sulphur in steel and cast iron.

Speed

The complete cycle for both the carbon and sulphur determinations with this new method takes only 4 min, including 30 sec to weigh the carbon result. Because the new method is a unification of two conventional procedures—which were speed methods initially—the time element has been cut in half. In addition, the electronic titrimeter eliminates the laborious hand-titrating step necessary in conventional sulphur analyses.

Greater Accuracy

The electronic titrimeter prevents the escape of sulphur, even in high sulphur samples, by titrating the SO_2 almost immediately as it enters the sulphur chamber. This does not allow an excess of SO_2 to build up and perhaps escape. This not only improves the accuracy of the sulphur determination but also that of the carbon determination, because any sulphur which escapes from the sulphur chamber could appear later as carbon, thereby destroying the exactness of the carbon determination.

More Dependability

The conventional methods for the determination of carbon alone must provide some safeguard, such as a manganese dioxide trap, to eliminate the interference of sulphur. These traps sometimes pass the point of usefulness by becoming "spent." Poor carbon results are obtained when sulphur is allowed to interfere. With the new setup, the sulphur is removed automatically, eliminating its interference.

More Flexibility

Occasionally, a sample submitted for analysis is so small that only one determination is possible. Under these circumstances, using the conventional methods, the analyst would have to choose either carbon or sulphur; the new method permits both determinations to be made from the same sample.

Economy

The new setup devised by GMC Truck & Coach chemists uses only one combustion boat, while the conventional method uses two. Additional savings occur on such factors as weighing time, electricity, oxygen, and equipment. The most important saving in using this method is in the analyst's time.

Acknowledgement

Acknowledgement is hereby given to a paper presented at the 1953 Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy entitled "Combined Method for the Determination of Carbon and Sulphur in Steel." This paper had three authors: Messrs. A. C. Holler and R. Klinkenberg of Twin City Testing and Engineering Laboratory and Mr. W. K. Aites of Westinghouse Air Brake Company.

The Ternstedt-Spray Process

By HOWARD E. SMITH
Process Development
Section

Electrical charges
guide paint particles
to a surface

Oftentimes, to those who have had little opportunity to study industrial manufacturng processes at firsthand, it may appear that the problems involved in the development of a new process are extremely complicated. In nearly every case, a process may be broken down into applications of one or more fundamental scientific principles, thus simplifying the solutions to the problems encountered by the development engineer. Such is the case in the application of electrical fundamentals to spray painting.

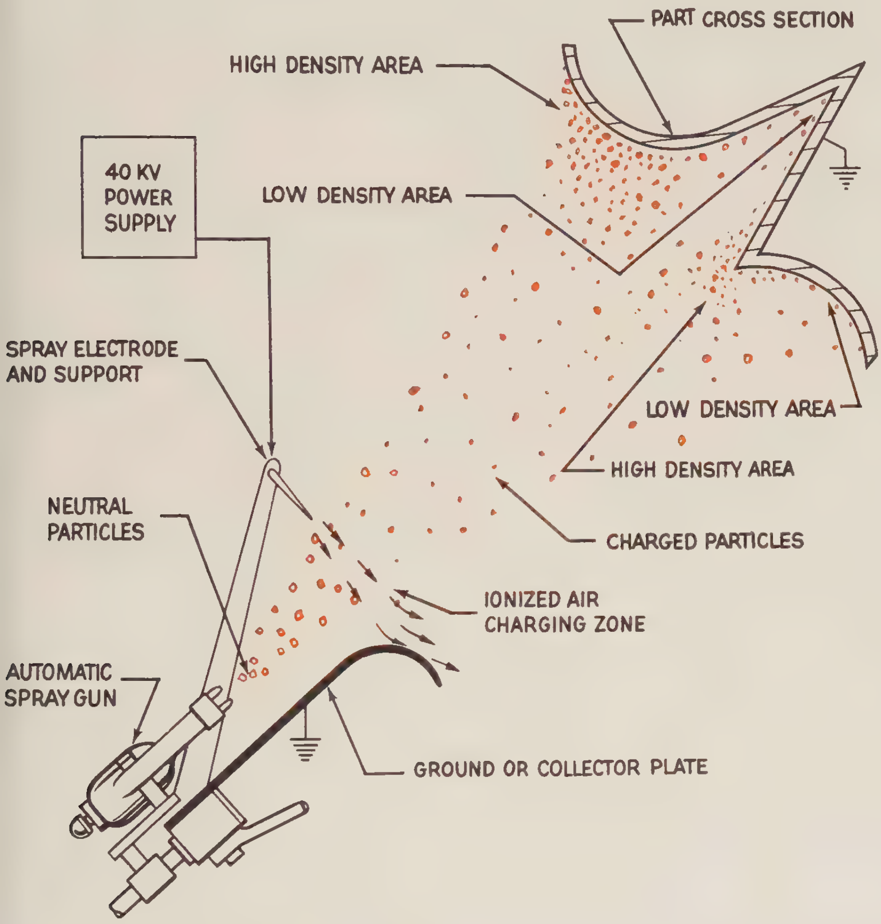


Fig. 1—The Ternstedt-Spray painting principle is illustrated in this schematic diagram. Paint is sprayed through an ionized field established between the needle electrodes and a grounded collector plate. The finely atomized paint particles are electrically charged to a high potential and, when sprayed in the direction of parts on a moving conveyor, are attracted to the parts which are grounded.

A COMPARATIVELY recent innovation in the application of decorative or protective coatings is that of electrostatic painting. For some time the Process Development Section of the General Motors Manufacturing Staff has been interested in this development and is continuing further studies of possible applications of the technique wherever spray painting is used. Known as Ternstedt-Spray, this electrostatic painting process was invented and developed by engineers in the Detroit plant of the Ternstedt Division of General Motors, primarily for use in painting automotive garnish or interior trim moldings.

Principle of Operation

The Ternstedt-Spray process depends for successful operation on a basic law of electrostatics, explained in any elementary physics textbook, that like electrical charges repel and unlike charges attract each other.

As a stream of paint emerges from a spray gun it is atomized into small particles by impinging streams of air. The paint particles are then projected through an ionized field wherein each picks up a static charge of electricity. Being directed initially toward a part to be coated which is at substantially ground potential, the charged particles of paint are attracted to the uncharged parts due to their difference in electrical potential. The ionized field is produced by an electrical paint spray charger which consists of a high-voltage needle electrode, a ground plate, and a plastic insulator. The needle electrode is connected to a high-voltage power supply which has an output of 40 kv at 50 microamperes to 70 microamperes current per charger. An electrostatic field is thus established and paint particles passing through this field are statically charged. Fig. 1 shows schematically the system used to electrostatically charge the paint spray.

Many of the inherent characteristics of paint deposition by the Ternstedt-Spray process, as well as by other electrostatic painting processes, are analogous in general to the characteristics of metal deposition by electroplating processes. Platers often experience difficulty in material deposition in deep recesses and particularly when shaped or contoured anodes are not used. By the same token, parts that are radically irregular are not

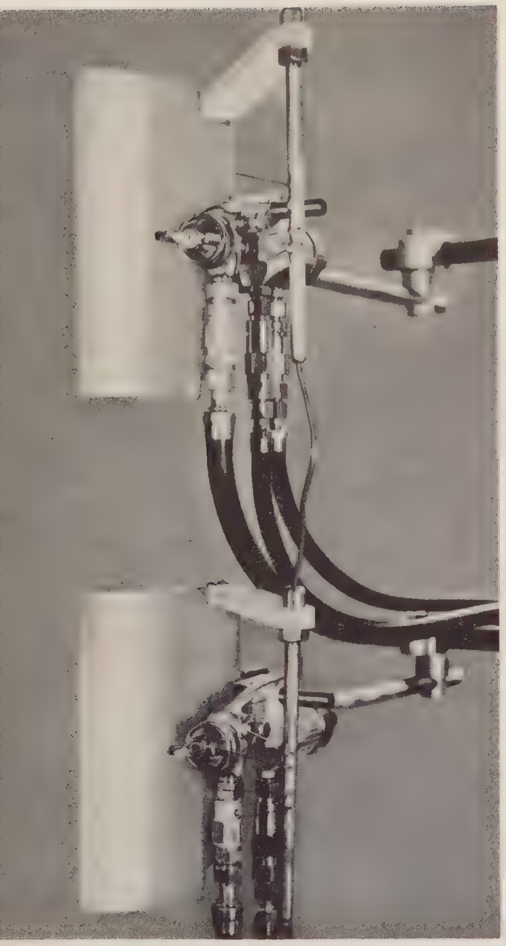


Fig. 2—The Ternstedt-Spray may be adapted to a two-gun installation whereby the direction of the spray may be properly aimed to achieve satisfactory coating on parts of irregular shape.

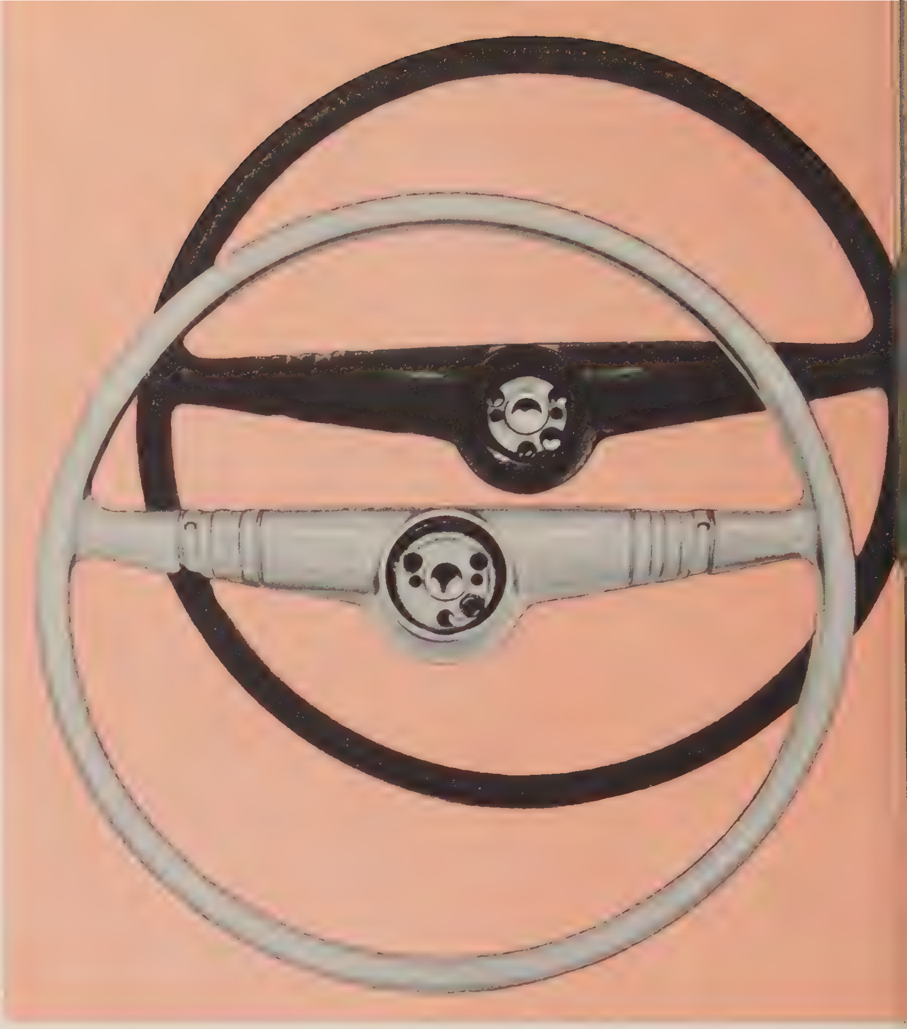


Fig. 3—In experimenting with the use of the Ternstedt-Spray for painting hard rubber steering wheels, it was found that when the high-voltage power supply was turned off the wheel was only lightly flecked with paint, as indicated by the darker wheel. The lighter wheel represents a satisfactory coating thickness achieved in a standard production installation.

easily plated uniformly. Pronounced projections of a part are usually plated more heavily than surrounding areas and depressions in the surface of a part are usually more lightly plated. These same basic principles apply to electrostatic painting, although to a varying degree.

Inasmuch as the charger and spray gun are mounted together, both the gun and charging field may be aimed and the paint spray, therefore, directed toward more inaccessible areas. This particular technique could be compared to the use of contoured anodes in plating since sections of a part that would otherwise receive a comparatively light coating can very often be painted more satisfactorily by the use of such a directional spray. A typical installation is shown in Fig. 2.

Advantageous Uses

In general, Ternstedt-Spray may be used to best advantage for parts in high volume production with which an inherently high over-spray loss is encountered when a manual spray process is used. This is the case with automotive garnish moldings for which the process was developed. Comparatively little over-spray loss occurs in the manual spraying of large parts that are nearly flat. In this case, only a very small percentage of material saving results from the use of the electrostatic process. Window garnish moldings, however, are reasonably large in overall dimensions with a very small amount of surface area to be coated. In addition, production rates are sufficiently high to warrant the cost of an automatic installation.

Quite often, the Ternstedt-Spray process can be used to advantage with relatively small or narrow sheet metal parts that have rolled or flanged edges. To properly paint the edges of such parts additional gun movements by the manual spray operator are required and only a small portion of the coating material is usefully applied to the part. Therefore, a considerable material saving results from the use of the electrostatic process.

In addition to the three plants of Ternstedt Division that have been using the Ternstedt-Spray process successfully for several years, installations have been made in other GM plants. One of the first of these installations was made at Inland Manufacturing Division approximately four years ago for the coating of hard rubber steering wheels. Several notable advantages have resulted from the adoption of Ternstedt-Spray for this operation. For example, there has been an increased production capacity, a saving in floor space for the same production volume, and an increase in product quality over the use of the manual method.

Fig. 3 shows two steering wheels painted experimentally under identical conditions except that the high-voltage power supply was turned off for the darker one. Close inspection of the illustration discloses that the darker wheel is only lightly flecked with paint. The other has a satisfactory production coating thickness.

Other installations of the Ternstedt-Spray process have been made at General Motors of Canada, Limited, Oshawa, Ontario, for the painting of automotive radiators and at Delco Appliance Division for painting fractional horsepower electric motors. At the Brown-Lipe-Chapin Division, Elyria, Ohio, plant this process was adopted for applying clear synthetic enamel over chromium-plated automotive parts during the recent period when the use of nickel in decorative chromium-plating was restricted. In addition, automotive oil filter shells are now being coated at AC Spark Plug Division by this process (Fig. 4).

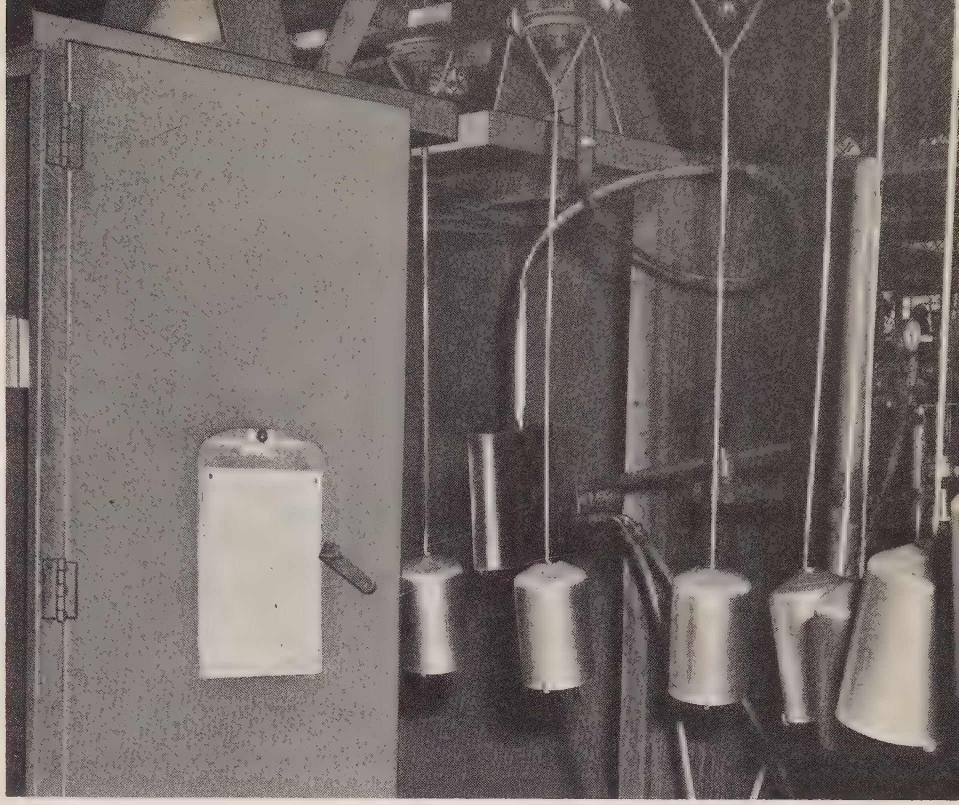


Fig. 4—Oil filter shells entering the electrostatic paint spray booth are coated with paint from a nozzle located at the booth entrance.

Paint Formulations

Various types of paint or coating materials have been successfully applied by the Ternstedt-Spray method. However, synthetic enamels are preferred. Asphalt-base paints also work satisfactorily. Basically, the most efficient electrostatic operation results when a very "wet" paint mixture or a material reduced with solvents of considerably higher boiling ranges than those commonly used for manual spraying are employed. Paint particles retain their static electrical charge only when liquid. Obviously, with the increased spray gun to work piece relationship, a characteristic of the automatic electrostatic method, a greater surface area of finely atomized paint particles is exposed for solvent evaporation for a much longer period of time. Therefore, in order to attain the same degree of "flow-out" and minimize the surface condition known as "orange-peel," more slowly evaporating or higher boiling solvents are required.

To date the use of lacquers with the Ternstedt-Spray process have not met with much success. Lacquers have a nitrocellulose base and are formulated with highly volatile thinners. Normal lacquer mixtures, even those prepared with the less volatile of the popular types of thinners, have been found to produce a mass of material that appears like "cotton candy" which covers the entire paint spray charger after only a few minutes of continuous spraying. To overcome this difficulty in one specific instance, it was found possible to do a satisfactory job by using a specially developed thinner containing approximately 20 per cent of diisobutyl ketone as one of the primary constituents. This extended the drying rate of the applied lacquer film enough to eliminate the "cotton candy" difficulty and remain within production drying time limits.

Savings

The economies resulting from the use of the Ternstedt-Spray process vary greatly with each application. Generally speaking, the direct material saving is of primary importance and reductions in paint usage range from 20 per cent to 70 per cent, depending on the type of part being painted. However, in some instances, the saving is chiefly in direct labor costs accompanied by an improved quality of surface coating.

Other intangible savings often result from an automatic installation of this type. Among these are reduced floor space requirements for a specific painting operation, since it has been found that two or more manual spray booths can often be replaced by a single, automatic electrostatic booth for the same production volume.

Still another allied saving of an indirect nature is the reduction in plant ventilating requirements. Inasmuch as personnel is not required in the immediate spraying zone while the painting is being done, the air laden with paint fog need not be exhausted quite so rapidly. This decrease in exhaust rate is also very beneficial in allowing maximum time for deposition of charged paint particles. The net result is increased painting efficiency and reduced plant heating and ventilation costs through conservation of conditioned air.

Conclusion

Engineers applying a fundamental principle of electrostatics to the process of applying decorative and protective coatings have developed the Ternstedt-Spray painting process. This process has been successfully used in applying surface coatings to a variety of products, resulting in savings of material, floor space, and plant ventilating requirements. In some cases, the use of this process has produced surface coatings superior to those when manual paint spray methods are used on the same parts. This emphasizes the need for a good working knowledge of scientific principles on the part of the practicing engineer in industry.

An Investigation of the General Metallurgy of Aluminum-Base Aircraft Alloys

By WALTER F. HELLER and
JAMES M. THOMPSON
Buick-Oldsmobile-Pontiac
Assembly Division*

Industry, especially during the past two decades, is recognizing more and more the growing importance of aluminum and its commercial alloys. One important impetus was the accent on air power during World War II which intensified the demand for aluminum and aluminum-base alloys because they exhibited three important properties required in aircraft bodies and parts—high strength, low weight, and resistance to corrosion. In the aircraft industry alone, the use of high strength aluminum alloys more than quadrupled during the war years. The Buick-Oldsmobile-Pontiac Assembly Division's Kansas City plant, with an eye on the increasing importance of aluminum-base alloys, has initiated a long-range laboratory study program in connection with its work on the F-84F Thunderstreak fighter-bomber. The objective is to establish complete data and photomicrographs on all of the common alloys used to date in aircraft design. The program covers the effects of underheating and overheating on the microstructures of the various alloys and the effects of the different thermal and aging treatments used.

How is aluminum affected by alloying elements, heating, and aging?

Today's modern airplane exemplifies industry's growing emphasis on light weight in engineering design. The expanding aircraft industry's need to unite the properties of light weight and a high strength-to-weight ratio provided the impetus for the recent development of new types of light non-ferrous alloys—especially those of aluminum. And the aluminum alloys, with their high strength, light weight, and good corrosion resistance, have proved especially applicable to aircraft design.

In February 1951 the Kansas City plant of the Buick-Oldsmobile-Pontiac Assembly Division was awarded a contract to manufacture the Republic-designed F-84F fighter-bomber. In order to provide a ready source of additional information on the majority of aircraft aluminum-base alloys used at this plant, B.O.P. metallurgists and engineers undertook a study of the microstructures encountered in the commonly used aircraft alloys and compiled information on the effects of thermal treatment. The results of the study gave information on the effects of overheating and underheating and suggested thermal treatments to obtain maximum strength without loss in corrosion resistance.

The study, so far, has covered 2024 (24S) and 7075 (75S) plate, bar, rod, sheet, and extrusions; 5052 (52S) and 6061 (61S) sheet and tubing; 2014 (14S) and 7075 (75S) forgings; and 356-T6 and 195-T6 casting alloys. (Each of the commercial aluminum alloys has a special designation generally recognized by industry; for example, alloy 2014 is aluminum alloyed with copper, silicon, manganese, and magnesium (Table I). The three- and four-digit indexing system was devised by the Aluminum Association and was officially effective on October 1, 1954. The two-digit numbers and the letters in the parentheses are part of the industrial designations used prior to the establishment of the new system and are included here and in Table I as a cross reference for those who are not yet familiar with the new designations. The letters and numbers following the hyphens refer to standard temper designations; for example, alloy 356-T6 denotes an aluminum-base alloy containing magnesium and silicon that has been solution heat treated and artifically aged without being cold worked after the heat treatment.)

The information and photomicrographs resulting from B.O.P.'s experimental work with 2024 alloy—one of the heat treatable aluminum alloys—are typical of the work completed on the other alloys.

2024 Alloy

Principal Constituents and Properties

The alloy 2024, developed around 1932, is a high strength *duralumin-*

COMPOSITION OF COMMON AIRCRAFT ALUMINUM-BASE ALLOYS

DESIGNATION—WROUGHT ALLOYS	ALLOYING CONSTITUENTS
2024 (24S)	4.4 per cent copper, 1.5 per cent magnesium, 0.5 per cent manganese
7075 (75S)	5.6 per cent zinc, 2.5 per cent magnesium, 1.6 per cent copper, 0.3 per cent chromium
5052 (52S)	2.5 per cent magnesium, 0.25 per cent chromium
6061 (61S)	1.0 per cent magnesium, 0.6 per cent silicon, 0.25 per cent copper, 0.25 per cent chromium
2014 (14S)	4.4 per cent copper, 0.8 per cent silicon, 0.8 per cent manganese, 0.4 per cent magnesium
DESIGNATION—CASTING ALLOYS	
356	7.0 per cent silicon, 0.3 per cent magnesium
195	4.0 per cent copper

Table I—This table lists the industrial designations and the constituents of some of the commercially important aluminum-base aircraft alloys under study at Buick-Oldsmobile-Pontiac Assembly Division. The numerical three- and four-digit indexing system was devised by the Aluminum Association and was officially effective October 1, 1954. The two-digit numbers and the letters in parentheses are the designations used prior to the introduction of the new system and are included as a cross reference for those who are not familiar with the new designations.

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*Both contributors were recently transferred from B.O.P. Assembly Division, where this paper was prepared, to other Divisions in General Motors. Mr. Heller is now at Harrison Radiator Division and Mr. Thompson is at Frigidaire Division.

type† alloy containing 4.4 per cent copper, 1.5 per cent magnesium, and 0.5 per cent manganese. Because aluminum in the commercially pure form has relatively low strength and poor machining and casting qualities, other elements are added to it in order to improve these properties. To illustrate: in the case of 2024, adding 4.4 per cent copper to aluminum increases the strength, hardness, and machinability of the alloy; adding 1.5 per cent magnesium increases the alloy's strength, corrosion resistance, impact resistance, ductility, and machinability; and adding 0.5 per cent manganese improves the corrosion resistance and the other *mechanical properties* of the alloy.

The principal constituents of 2024 are (Al-Cu-Mg), (Al-Cu), (Mg-Si), and (Al-Cu-Fe-Mn) particles. The iron Fe and the silicon Si present are impurities carried over from the aluminum ore into the commercially pure metal; the aluminum ore, bauxite, contains both iron oxide Fe_2O_3 and silica SiO_2 as its principal impurities. Also, some of the iron present may be the result of the solvent action of aluminum on the ferrous equipment used during the processing of the alloy.

The (Al-Cu-Mg) and (Al-Cu) particles are appreciably soluble, whereas (Mg-Si) and (Al-Cu-Fe-Mn) particles are essentially insoluble and various heat treatments have virtually no effect on their *grain* shape, size, and general distribution.

As a general rule, the aluminum alloys have high corrosion resistance—the result of a thin, continuous, and tightly adhering film of aluminum oxide formed on the alloy's surfaces that come into contact with air. Besides this, various industrial methods of coating the alloy's surfaces to increase corrosion resistance are used. One of the most common is painting; the other is the application of a high-purity aluminum sheet to one or both surfaces of the alloy, called *cladding*. In most cases Alclad sheet is used. Alclad has a strong alloy core covered with a thin layer of high-purity aluminum or an alloy whose composition provides electrolytic protection for the alloy underneath. In the case of 2024 alloy, not only is the resistance to corrosion greatly increased by the covering action of the high-purity aluminum clad, but also corrosion resistance is raised by the electrolytic protection of the alloy underneath (called the *core*) by the clad coating.

One of the factors influencing the degree of corrosion resistance of 2024 is the extent of the diffusion of copper, magnesium, and other elements from the alloy-proper into the clad. The amount of diffusion is influenced by the temperature and the duration of heat treatment and can be detected by metallographic examination, using the X-ray or the electron microscope.

SUGGESTED SOLUTION HEAT TREATMENT TIME AND TEMPERATURES

WROUGHT ALLOYS	TEMP. (° F)	TIME FOR GIVEN THICKNESS (MINUTES) (UP TO 0.032 IN.)	(OVER 0.032 IN. TO 0.125 IN.)	(OVER 0.125 IN. TO 0.250 IN.)	(OVER 0.250 IN.)
2014	925 to 950			30	60
2024	910 to 930	20	30	40	60
2024 Alclad	910 to 930	20	30	40	60
7075 Plate Sheet, Strip	860 to 930	25	30	40	60
7075 Clad Plate, Sheet, Strip	860 to 930	25	30	40	60
6061	960 to 1,010	20	30	40	60

FORGING ALLOYS	TEMP. (° F)	TIME FOR GIVEN THICKNESS (HOURS) (UP TO 2 IN.)	(OVER 2 IN.)
2014	925 to 950	0.5 to 6.0	2.0 to 12.0
7075	860 to 890	0.5 to 6.0	2.0 to 12.0

Table II—Because overheating and underheating during solution heat treatment destroy the alloy's mechanical properties, both the temperature and the duration time of heat treatment must be closely regulated. The time and temperature specifications in this table were determined experimentally at B.O.P.

Use in Aircraft Design

In this modern age of jet propulsion and its accompanying high speeds, the structure of an aircraft must receive primary consideration. Because the alloys 2024 and 7075 possess the highest tensile and yield strengths of all the commercial aluminum-alloy products, they are used extensively in the basic structure of today's aircraft. The leading edge of the wings and many of the wing panels are made from 7075-T6 sheet and plate, while the other skin assemblies on the wing and fuselage are manufactured from 2024-T4. (The T4 temper designation means that the alloy was solution heat treated and then aged naturally.)

Forgings of 7075-T6 and 2014-T6 alloys are used as basic structural members, while 7075-T6 extrusions are used as stringers.

Aluminum-alloy castings are utilized where extremely high strengths are not required, as in the engine. The 5052 alloy is primarily used for all fusion welded parts, while 6061 has only limited usage.

General Heat Treatment of Aluminum Alloys

Heat treatable alloys are those which contain elements, groups of elements, or constituents which are soluble at high temperatures and have restricted solubility at lower temperatures; for example, in 2024 alloy, these are the (Al-Cu-Mg) and (Al-Cu) particles. One of the main objectives of subjecting alloys to thermal treatment is to produce the required mechanical properties in the finished alloy. This is accomplished through a controlled process of heating and cooling the material in a solid state in such a way that the size and distribution of the precipitate formed are regulated. (The strength of a heat treatable alloy is a result of the uniform distribution of a finely dispersed submicroscopic precipitate and the distortion of its grain structure.)

To put the soluble constituents of an alloy into solution and to prevent or retard their immediate re-precipitation, a thermal treatment called *solution heat treatment* is used. This process consists of (a) putting the soluble elements into solution by raising the alloy's temperature as high as possible above its solubility curve and (b) retarding the re-precipitation of the soluble elements by rapid *quenching*.

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†For glossary of some metallurgical terms, please see page 30.

SUGGESTED PRECIPITATION HEAT TREATMENT TIME AND TEMPERATURE

Wrought Alloys	Aging Time (Hours)	Aging Temp. (° F)
2024-T4	96	Room Temperature
2024-T4 Clad	96	Room Temperature
6061-T6	12 to 20	310 to 330
7075-T6	24	240 to 260
7075-T6 Clad	24	240 to 260
Forging Alloys	**Aging Time (Hours)**	**Aging Temp. (° F)**
2014-T6	5 to 14	330 to 360
7075-T6	24	240 to 260

Table III—To assure maximum strength, aluminum alloys are precipitation hardened or aged after solution heat treating and quenching. As this table indicates, some alloys obtain their strength at room temperature, while others require artificial aging treatment. For the desired mechanical properties, each alloy must be precipitation hardened according to specifications. For example, if alloy 2024 was artificially aged, the result would be an alloy with totally different mechanical properties than 2024 aged at room temperature.

Conditions of Heat Treatment

The temperature of the *bath* should not be higher at any time during the period of heat treatment than the maximum temperature specified for the heat treatment of that particular alloy. (Table II lists the heat treating temperature ranges of some aluminum alloys.) If the maximum temperature is exceeded there is a possibility that *eutectic melting* may occur, destroying the alloy's mechanical properties and giving an undersirable surface appearance. However, if the material is not heated to the minimum temperature, the full mechanical properties will not be developed and the alloy's resistance to corrosion will be lowered.

The duration time of the heat treatment is measured from the moment that the coldest part of the load reaches the minimum operating temperature of the heat treating range. The amount of time at that temperature varies with the thickness and the type of alloy (Table II). For clad-wrought alloys, the minimum possible time should be used in order to prevent the diffusion of the alloying constituents of the core through the clad to the surface.

The time interval from the bath to the quench tanks should be as short as possible—a matter of seconds. Allowing the metal to cool in air is equivalent to quenching from a low heat treating temperature, which produces low mechanical properties and low resistance to corrosion. Wrought alloys should be quenched in cold water when warpage from quenching is unimportant. Quenching in air, hot water, or oil may produce the desired mechanical properties, but the corrosion resistance of the alloys quenched in these media is inferior to those quenched in cold water.

Precipitation Hardening of Aluminum Alloys

For maximum strength, after solution heat treating and quenching, the alloy must be *precipitation hardened* or aged. During the high temperatures of solution heat treatment the hardening constituent —which in 2024 alloy is principally (Al-Cu)—is in solution. Rapid quenching in cold water retains it in solution. Because of the decreased solubility of the hardening constituent at lower temperatures, the *solid solution* is now in a supersaturated condition. In this unstable condition, the excess atoms tend to form aggregates and these coalesce into particles or *precipitate*. This precipitation prevents movement within the aluminum crystals and, thus, the alloy hardens.

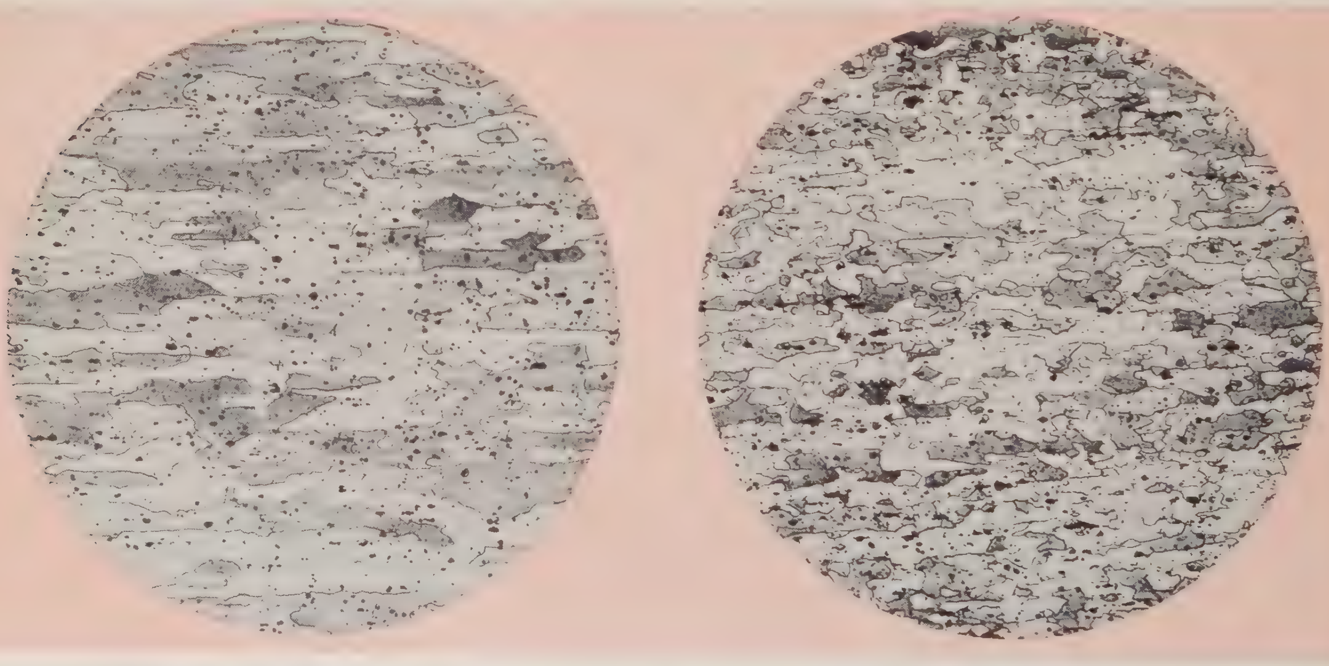


Fig. 1—After 2024 has been solution heat treated, it is aged at room temperature. During the aging period, the magnesium and silicon atoms in the alloy combine to form the intermetallic compound Mg_2Si which increases the strength and hardness of 2024. The particles scattered through the 2024 alloy cross sections in these two photomicrographs are chiefly Mg_2Si. The alloy on the left (2024-T3) has been solution heat treated and then cold worked to improve its strength. The alloy on the right (2024-T4) was solution heat treated, followed by aging at room temperature to a substantially stable condition. (Cross sections magnified 100 times.)

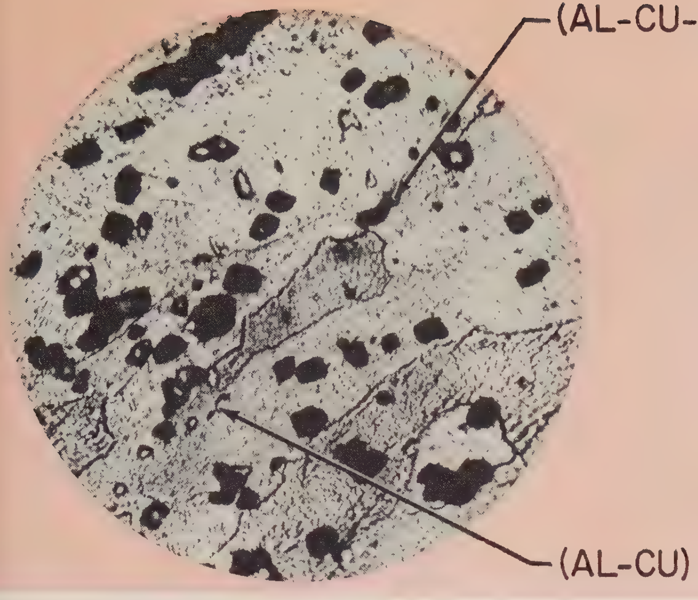


Fig. 2—This photomicrograph shows the grain structure of 2024-T4 sheet (solution heat treated and naturally aged) that was underheated at 870° F for only 5 min. (Table II lists correct temperatures and time.) This was too low a temperature and insufficient time to allow the (Al-Cu-Mg) and (Cu-Al) constituents to go into solution. As a result, these particles are present and grain contrast is low. (Cross section magnified 100 times.)

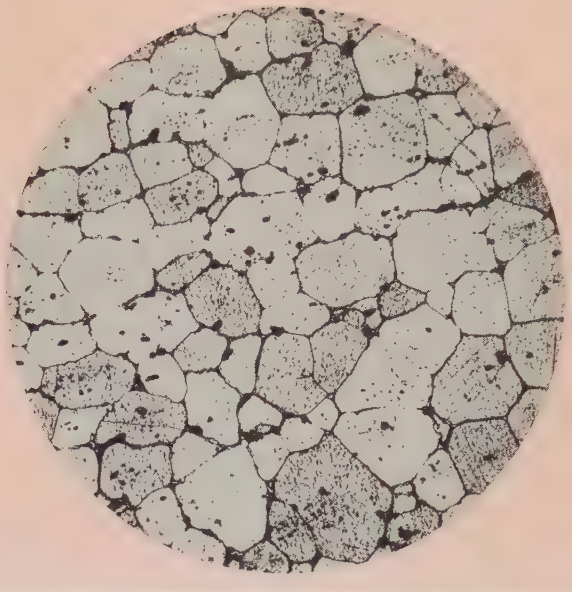


Fig. 3—This 2024-T4 sheet was overheated at 1,050° F for 35 min. (Table II lists correct temperatures and time.) The high temperature caused melting of the eutectic areas and of the solid solution along the grain boundaries. (Cross section magnified 100 times.)

As the precipitation of the excess soluble constituents takes place, the strength of the material increases, often by a series of peaks, until a maximum is reached. By continuing the aging process beyond this maximum point, the alloy's strength begins to decline steadily until a somewhat stable condition is reached.

The heat treated aluminum alloys are divided into two classes: naturally aging alloys that obtain their strength at room temperature (2024 is one of these), and those alloys that require an artificial aging treatment (Table III).

Naturally aging alloys obtain their full strength after four or five days at room temperature. Precipitation of soluble constituents starts soon after quenching, with 90 per cent of the maximum strength being obtained after 24 hr.

While the artificially aging alloys require thermal treatment to develop their full strength, these alloys also age a limited amount at room temperature.

Heat Treatment of 2024 Alloy

Aluminum alloys containing from 2 per cent to 12 per cent copper—2024 falls into this category—are good examples of alloys that can be improved by solution heat treatment followed by aging. When 2024 is heat treated in the range of 910° F to 930° F for the specified amount of time as listed in Table II, the principal soluble constituents (Al-Cu-Mg) and (Al-Cu) are dissolved in the aluminum to form a solid solution *matrix*. It is possible to retain these soluble alloying elements in solution by rapid quenching. Subsequent aging of 2024 at room temperature for several days after heat treatment allows some of the alloying elements to migrate and re-form very minute particles of precipitate. This precipitate, which is submicroscopic, greatly increases the strength and the hardness of the solid solution matrix.

At this point, the microstructure of the heat treated 2024 alloy consists of a solid solution matrix containing insoluble particles of (Al-Cu-Fe-Mn) and Mg_2Si, as well as undissolved particles of (Al-Cu-Mg) and $CuAl_2$. The aluminum and the copper atoms in (Al-Cu) have reacted to form the *intermetallic compound* $CuAl_2$, copper aluminide, which is the hardening constituent of 2024 alloy. Magnesium and silicon atoms in (Mg-Si) particles have combined to form the intermetallic compound Mg_2Si which increases the strength and hardness of 2024 but lowers its ductility somewhat (Fig. 1). (Each of the specimens in the photomicrographs used with this paper was etched using Keller's etch and the cross sections magnified 100 times, with the exception of Fig. 4 which is magnified 1,000 times.)

Underheating

Referring to the suggested solution heat treatment time and temperatures for 2024 alloy given in Table II, the following are some of the effects noted when 2024 was underheated. Heat treating 2024 at the proper temperature, but for an insufficient time, produces only the partial solution of the soluble alloying constituents—(Al-Cu-Mg) and (Al-Cu); therefore, the photomicrograph of 2024 heat treated in this manner shows undissolved particles of (Al-Cu-Mg) and (Al-Cu). Heat treating at lower temperatures than specified in Table II produces almost the same photomicrograph as heat treating at proper temperature for an insufficient amount of time. The principal difference will be the amount of grain contrast developed; heat treating at 910° F to 930° F for 1 min will show more grain contrast than heat treating at low temperatures for the proper duration of time. Fig. 2 shows the grain structure of a sheet of 2024 alloy that has been solution heat treated and naturally aged to a substantially stable condition. This sheet was underheated at 870° F for only 5 min. This was too low a temperature and insufficient time for the soluble constituents (Al-Cu-Mg) and (Al-Cu) to go into solution. As a result, these particles are present and the grain contrast is low. (In aluminum-copper alloys, failure under stress, in most cases, occurs through the grains (called *intercrystalline corrosion*) instead of at the grain boundaries. Consequently, to maintain strength under repeated stresses, grain contrast is a prime necessity.)

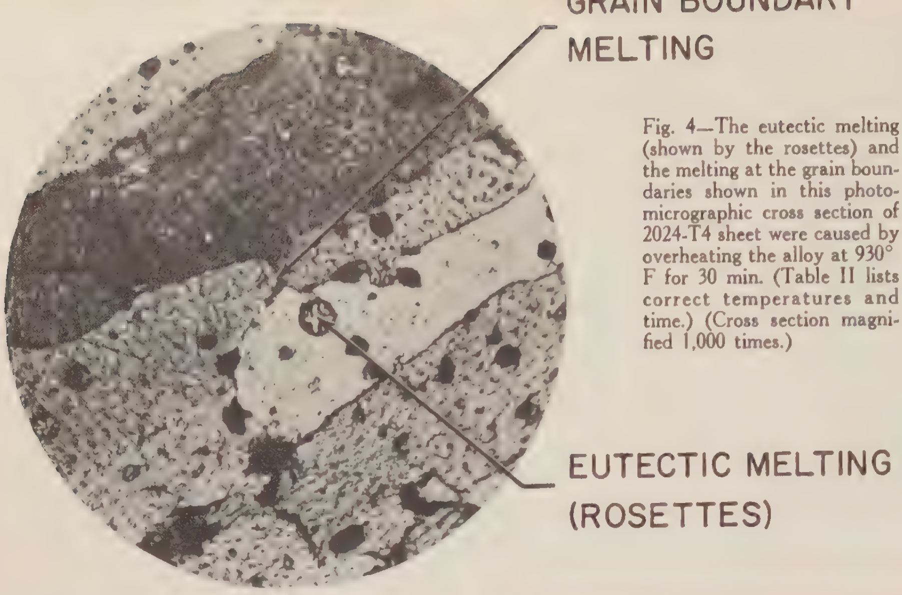


Fig. 4—The eutectic melting (shown by the rosettes) and the melting at the grain boundaries shown in this photomicrographic cross section of 2024-T4 sheet were caused by overheating the alloy at 930° F for 30 min. (Table II lists correct temperatures and time.) (Cross section magnified 1,000 times.)

Overheating

If the heat treating range is extended beyond 936° F *incipient melting* occurs (Fig. 3). (Incipient melting starts at approximately 1,018° F.) Overheating also causes small areas of eutectic melting and some fusion at the grain boundaries which lower the alloy's strength (Fig. 4).

The aircraft designer, when selecting an alloy, bases his design on the highest possible strength and hardness of that alloy. Any heat treatment above or below the specified requirements results, therefore, in lower strength and hardness and, thus, an unsound design.

Conclusion

While this paper covered in detail only the work done with the 2024 alloy, the study program at B.O.P. is set up to investigate and compile complete information on the chemical composition; the mechanical properties; the effects of solution heat treatment, annealing, and precipitation hardening; and the casting and forging qualities of all of the principal aluminum-base alloys used in aircraft design (Table I). These include:

- 2014, a forging, duralumin-type alloy used for propeller blades, connecting rods, crankcases, and other miscellaneous aircraft fittings
- 7075—the most common high-strength aluminum alloy—available in extruded forms and clad sheeting
- 5052, an aluminum-magnesium alloy which combines the advantages of low cost, high corrosion resistance, and the ability to be readily formed and easily welded
- 6061, a heat treatable alloy with good general resistance to corrosion
- 195, a commercially important, heat treatable, casting aluminum alloy with good machining characteristics, high mechanical properties, and high strength. This alloy is usually utilized for structural aircraft parts in which the strength-to-weight ratio is important.
- 356, another casting aluminum alloy with excellent casting qualities, good pressure tightness, and a high resistance to salt water corrosion. It is used in aircraft for pistons, cylinder heads, and crankcases.

Glossary

For paper beginning on page 26: "An Investigation of the General Metallurgy of Aluminum-Base Aircraft Alloys."

A **bath** is a medium—for aluminum alloys, it is molten (liquid) salt—used in regulating the temperature of the alloy placed in it.

Duralumin, with the industrial designation 2017, is an aluminum-base alloy containing 4 per cent copper, 0.5 per cent magnesium, and 0.5 per cent manganese. The term *duralumin-type* is applied, in general, to those wrought aluminum-copper-magnesium alloys that harden during aging at normal room temperature.

Eutectic refers to the one particular alloy in an alloy system with the lowest melting point in that system. The term *eutectic melting* pertains to the melting that takes place in the specific microscopic areas of an alloy having the same atomic make-up as the eutectic alloy.

Grains are particles of a metal or an alloy comprised of a large number of minute crystals arranged in definite geometric patterns. The properties of an alloy or a metal are intimately related to its grains' size, shape, and chemical composition.

Incipient melting of the lower melting constituents occurs when excessive temperatures are used in solution heat treatment. Also known as "overheating," incipient melting results in a loss of ductility and strength and produces blisters and cracking during quenching.

Intermetallic compounds are substances formed by the chemical union of metals with metals. They differ from ordinary compounds composed of metals united with non-metals in that they usually do not follow the rules of valence (for example, $CuAl_2$). They are hard and brittle, have low electric conductivity, and have complex crystalline structures.

The **matrix** of an alloy is the main substance of an alloy in which the constituents are imbedded. As a rule, the matrix is the last component of an alloy to be solidified.

Mechanical properties are those characteristics of a metal or an alloy which give its resistance to a steadily applied load; for example, tensile strength, compressive strength, torsional strength, bending strength, hardness, and yield strength.

Quenching is a method of quickly cooling a metal or an alloy from high temperatures by immersion in a solid (ice), liquid (water or oil), or a gas (air).

A **solid solution** is a solid-state mixture of the atomic particles of the metallic components of an alloy—the atoms of one or more metals suspended in another metal. In the molten state, all metals—with few exceptions—are mutually soluble in each other; one metal dissolves in another. Solid solutions have all the characteristics of liquid solutions, with the exception of mobility.

Notes About Inventions and Inventors

By ROBERT R. CANDOR
Patent Section
Dayton Office Staff

The Freon refrigerants—how basic patents allowed full development for public use

THE present younger generation may not know it but, as late as the early 1920's, the iceman and the icebox were national institutions. In a sense, they were both jokes. The icebox kept things cool but not cold. Consequently, the butter was often rancid and the meat often spoiled. It was said that a thunderstorm could sour the milk in the icebox. But everybody had to accept such shortcomings.

In the middle '20's, the electric refrigerator made its appearance in earnest. It began to drive out the iceman and the icebox. General Motors adopted a trademark showing an iceman bringing a refrigerant evaporator, instead of a block of ice, into the home and proceeded to make the name Frigidaire a well known name in electric refrigeration. The butter now was always fresh, and the meat was beyond reproach. The milk was cold and always sweet, regardless of the weather. The new thrill which was added was the serving of cold drinks with ice cubes in them.

However, everything was not rosy. A day would come when strong pungent odors would fill the house and silver and other objects would become unduly tarnished. The refrigerant in the electric refrigerator was making itself known. In the case of sulphur dioxide, the most common refrigerant of the day, the odor was strong enough to drive the people from the house before injuring them.

Other refrigerants were not so kind. Many were odorless but could make people violently sick and, it was said, could actually kill them.

The electric refrigeration industry was growing by leaps and bounds, and was looking for new fields to conquer. It wanted to fill apartment houses with refrigerators. It wanted to condition the air in homes, small theaters, and other places, by direct contact between the refrigerant evaporator and the air being conditioned. The electric refrigeration industry wanted to place large electric refrigerators in groceries, markets, and the like. But the lawmakers and the code men were beginning to doubt the wisdom of this. A movement was on foot to limit the amount of electric refrigeration which could be concentrated where dangerous to people. So the new infant industry was about to be gravely hampered in its growth.

The scene for the rescue was set. A new line of safe refrigerants was invented and developed. They were patented in Reissue Patent No. 19,265. Dr. Thomas Midgley, Jr. had just completed his development of ethyl gasoline which took the "ping" and stall out of the automobile. He was called into the refrigeration industry by Dr. Charles F. Kettering to solve the refrigerant problem. With the able assistance of Dr. Albert L. Henne and Robert R. McNary, the refrigerant field was explored and, finally, the solution was found in the "fluoro-halo derivatives of the aliphatic hydrocarbons" which were practically unknown, in a commercial sense, at that time. There was no source of supply, and very little was known of their properties.

The manufacture of the new refrigerants was, in itself, a major undertaking, requiring years of effort. After this was accomplished, refrigerators had to be modified to use the new refrigerants. At one time, the cost of such modification was so large that the program was practically discarded. However, when success was finally achieved, the electric refrigeration industry universally adopted these refrigerants. Complete freedom of installation is permitted, with the knowledge that there is no danger of poison or odor.

The scene was similar to a feature television show. The inventors were the star actors. There was a sponsor with the necessary capital to finance the project and a tremendous supporting cast including many skilled technicians. But there was also a difference; the refrigerant show lasted for several years.

Since this development was profitable to the sponsor it was an inspiration to future development. Basic patents were granted and respected, and the entire development was profitable. Among the more important patents on refrigerants were Reissue Patent No. 19,265 on Heat Transfer and three on Heat Transfer and Refrigeration, Nos. 1,968,049, 1,968,050, and 2,104,882. Among the more significant patents on the manufacture of refrigerants were No. 1,930,129 on Manufacture of Aliphatic Fluoro Compound; No. 2,007,208 on Manufacture of Fluoro Derivatives of Aliphatic Hydro-carbon; and No. 2,013,062 on Preparation of Aliphatic Halo Fluoro Compounds.

The prosecution of the patent applications avoided certain dangers inherent in a long development. Since the development extended over many years, knowledge of it naturally leaked out. It was only by the filing of early patent applications that the rights of the inventors were preserved against unauthorized publications by others who learned of the development. These early applications disclosed all that was known during the early development, and made certain that the inventors' patent rights were not affected by such unauthorized publications. As the development progressed, later and improved patent applications were filed which replaced these early applications, but with the benefit of their early filing dates. The later applications included information about certain compounds explored at the request of the General Motors Patent Section after the filing of the early applications. The inventors cooperated very closely and in a helpful manner in obtaining the requested information and in the preparation of these later applications. So the patents which were finally issued furnished the protection which the invention deserved and included specifically the later developed compounds.

The history of this development, and of its patent prosecution, shows that it is well to file a preliminary patent application as early as possible after all of the fundamental principles are known, and long before the final development is reached. Later, improved applications can be filed if further information is obtained concerning the invention. This is particularly true in chemical cases. Engineers would do well to contact their patent attorneys as early and as frequently as possible when a long-term development is in progress. By so doing, they will insure that delay in filing patent applications does not jeopardize the value of the patents, when issued, and also will insure that all of their later development is also protected.

On this and the following pages are listed some of the patents granted to General Motors prior to March 16, 1955. The brief patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each patent.

*Biographies of inventors whose names are marked with an asterisk have been published in previous issues of Volume 2, General Motors Engineering Journal.

Patents Granted

- **Everett L. Baugh,** *Cadillac Motor Car Division, Cleveland, Ohio, for an Electro-hydraulic Control and Actuating System for a Vehicle Top, Window, and Seats, No. 2,696,403, issued December 7.* This patent relates to an electric system for actuating hydraulic controls for the windows and seats and convertible top of a vehicle in which there are both primary and secondary control stations with the primary station arranged to override the secondary station.

- **Everett L. Baugh and DeLoss D. Wallace,** *Cadillac Motor Car Division, Cleveland, Ohio, and Moraine Products Division, Dayton, Ohio, respectively, for a Pump for Hydraulic Actuator Systems, No. 2,698,515, issued January 4.* This patent relates to control valving for a pump that prevents high pressure fluid from backing up into the pump from the discharge line when the pump has stopped.

Mr. Baugh has served as chief engineer at Cadillac Motor Car's Cleveland Tank Plant since February 1955. In 1941 Mr. Baugh joined Delco Brake Division (later was merged with Moraine Products) as a junior project engineer in the Engineering Laboratory. He transferred to the Cleveland Tank Plant in 1950 as assistant staff engineer. Mr. Baugh earned the B.M.E. degree in 1938 from The Ohio State University and did graduate study work at Massachusetts Institute of Technology.

Mr. Wallace is a section engineer in Moraine Products' Engineering Department. In 1928 (two years after earning the B.M.E. degree from The Ohio State University) he joined Frigidaire Division as a development engineer until 1936. In 1943 he rejoined General Motors at Moraine Products. This is the tenth granted patent in the fields of hydraulic equipment, powder metallurgy, filters, sterilizers, and dishwashers resulting from Mr. Wallace's work. He is a member of the Engineers' Club of Dayton and is a registered professional engineer in the State of Ohio.

- **Paul L. Schneider* and William H. Taylor,** *Delco-Remy Division, Anderson, Indiana, for an Engine Starting Apparatus, No. 2,696,121, issued December 7.* This is an engine starting device in which the starter pinion is automatically moved into engagement with the engine flywheel gear and is held in engagement therewith during cranking by a positive lock which is released only when the starting motor circuit is opened.

Mr. Taylor is group leader of switches in Delco-Remy's Drafting Department. His experience, since joining the Division as a blueprint operator in 1922, has included draftsman (1923), material specification clerk (1928), carburetor designer and special assignment (1940), and group leader of switches (1952)—his present position. This is the first patent granted as a result of Mr. Taylor's work.

- **Carl A. Stickel,** *Patent Section, Dayton, Ohio, for a Refrigerating Apparatus and Water Heater, No. 2,700,279, issued January 25.* In this patent a water heater is heated by the waste heat given off by the condenser of a dual refrigerating system which cools a freezer as well as the room.

Mr. Stickel is a patent attorney in the Dayton Office of the General Motors Patent Section. He joined GM in 1930 as a member of the Frigidaire Division Patent Department. Admitted to the Ohio Bar in 1932 and the Federal District Court in 1934, he received his M.E. degree in 1927 and LL.B. degree in 1932 from The Ohio State University and University of Dayton, respectively. He was awarded his M.P.L. (Master of Patent Law) degree by University of Dayton in 1934. Sixteen patents in the field of refrigeration and appliances have resulted from his work.

- **Joe White and Clarence J. Keller,** *Delco-Remy Division, Anderson, Indiana, for an Electromagnetic Horn, No. 2,700,761, issued January 25.* This patent deals with an electromagnetic horn in which the frame structure is formed from sheet metal and in which the various parts are supported upon the frame in predetermined relation thereto.

Mr. White is section head on horns in Delco-Remy's Engineering Department.

He joined the Division in 1925 as a student engineer after earning the B.S. degree from Rose Polytechnic Institute. He was promoted to his present position in 1933. Mr. White is a member of the honorary society Tau Beta Pi. His work with automobile horns has resulted in more than ten granted patents.

Mr. Keller is no longer with the Division.

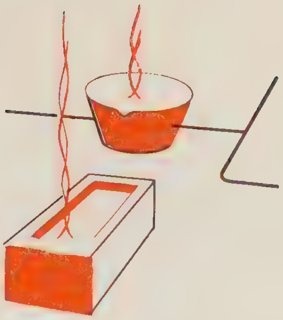
- **Harry C. Doane,** *Buick Motor Division, Flint, Michigan, for a Clock Setting and Regulating Mechanism, No. 2,700,867, issued February 1.* This patent relates to a clock setting and regulating mechanism comprising concentric shafts projectng through the face of the dial.

- **Harry C. Doane,** *Buick Motor Division, Flint, Michigan, for an Electrical Connector, No. 2,703,872, issued March 8.* This patent relates to a one-piece electrical terminal in which a part of the stock is turned up at the entrance end to provide a guard for preventing accidental injury to the resilient terminal fingers.

Mr. Doane has served as assistant chief engineer at Buick Motor since 1949. In 1924 he transferred to this Division as a staff engineer in the Electrical Division after a seven-year employment with Remy Electric Company, predecessor of Delco-Remy Division. Mr. Doane's work in the fields of mechanical and electrical engineering has resulted in 22 granted patents and two published technical papers. His technical affiliations include, in part, the S.A.E., Automobile Manufacturers Association, GM Ignition Committee, and the U.S. National Committee of the International Commission on Illumination.

- **Robert E. Field,** *GMC Truck & Coach Division, Pontiac, Michigan, for a Governor Adjusting Means, No. 2,700,962, issued February 1.* This patent relates to a self-sealing diaphragm associated with the drain plug of an engine oil pan through which a tool may be inserted when the plug is removed to adjust the speed governing element of a hydraulic governor driven from the engine lubricating oil pump.

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.



Mr. Field is drafting supervisor—engines in GMC Truck & Coach's Engineering Department. In 1933 he was employed by this Division as a co-op student of General Motors Institute. He was graduated from the Institute in 1937 and received the B.M.E. degree in 1949. After a series of promotions within the Engineering Department he was named to his present position in 1948. This is the first patent granted as a result of his work. Mr. Field is a member of the Society of Automotive Engineers.

- **William J. Purchas, Jr. and Edward Orent,** *Diesel Equipment Division, Grand Rapids, Michigan, for a Duplex Fuel Nozzle, No. 2,701,164, issued February 1.* This patent relates to a duplex swirl-type fuel spray nozzle for gas turbine engines with an annular plate between two coaxial swirl chambers, the first chamber discharging into the second, and the second into the engine.

Mr. Purchas is chief engineer of Diesel Equipment. He received the B.S.M.E. degree from Detroit Institute of Technology in 1933. Mr. Purchas began his career with General Motors in 1936 as a dynamometer operator with the Research Laboratories Division. In late 1936 he was promoted to the Drafting Department, engaged in injection design. In 1938 he transferred to the Detroit Diesel Engine Division as project engineer on fuel injection. In 1945 he became a senior engineer at Diesel Equipment and in 1949 he was promoted to chief engineer, his present position. Mr. Purchas is a member of the S.A.E. and the Engineering Society of Detroit.

Mr. Orent is superintendent of Diesel and aircraft activities in the Production Department at Diesel Equipment. He was originally employed by Detroit Transmission Division in 1944 as design layout engineer in the Engineering Department. In 1945 he transferred to Diesel Equipment as a design checker. He was promoted to project engineer in 1946, to senior project engineer in 1950, to superintendent of Aeroproducts activities in 1953, and to his present position in early 1955. Mr. Orent received the B.S.M.E. degree from University of Michigan in 1944. He is a member of the Society of Automotive Engineers, Phi Kappa Phi, and Tau Beta Pi.

- **Walter E. Sargeant* and Edward F. Weller, Jr.*,** *Research Laboratories Division, Detroit, Michigan, for an Electric Pickup, No. 2,701,335, issued February 1.* This patent concerns an electromagnetic spark pickup having a toroidal winding through which the spark plug lead projects, and having means for electrostatically shielding the winding from the spark plug lead.

- **Bertram A. Schwarz* and Manfred G. Wright,** *Delco Radio Division, Kokomo, Indiana, for a Motor-operated Tuning Means, No. 2,701,330, issued February 1.* The invention in this patent relates to the mechanical portion of a signal seeking radio tuner including the resiliently powered motor and re-cocking solenoid for moving the tuning means and scanning the frequency band of the receiver.

Mr. Wright has served as head of Delco Radio's Mechanical Engineering Section since 1950. He started in the Division's Inspection Department in 1938 after earning the B.S.M.E. degree from Purdue University. He transferred to the Engineering Department as a project engineer in 1943. This is the seventh patent resulting from Mr. Wright's work with radio tuning and dimensional gaging devices. He presented a paper on four-bar linkage mechanisms at the Purdue University 1954 Conference on Mechanisms.

- **Robert E. Young,** *New Departure Division, Bristol, Connecticut, for a Ball Inspection Gage, No. 2,700,889, issued February 1.* This invention relates to a ball inspection gage wherein a ball being inspected is rotated about an ever-changing axis while the ball is supported by the sharp circular edge of a Carboloy seat. Leakage of air between the ball and its seat indicates non-sphericity as well as minor errors in the ball surface.

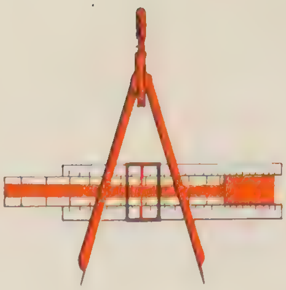
Mr. Young was director of inspection for New Departure at the time of his retirement in 1953. Forty-one years previously he joined this Division's Bristol, Connecticut, Mechanical Department as a tool maker. In 1913 he transferred to the Elmwood, Connecticut, plant in this same capacity and transferred to the Meriden, Connecticut, plant in 1932 when that plant absorbed the Elmwood operation. Highlights of Mr. Young's GM career include: foreman of assembly and final inspection (1914), foreman of cone ball race grind (1924), chief inspector (1933), and director of inspection (1947). He is a charter member of the Hartford, Connecticut, Engineer's Club and a past chairman of the GM Chief Inspectors' Committee (1951).

- **Robert R. Candor***, *Patent Section, Dayton, Ohio, for an Expansion Valve for a Refrigerating Apparatus, No. 2,701,451, issued February 8.* This patent relates to a refrigerant expansion valve which prevents overloading of the compressor by providing a lost motion connection between its thermostatic diaphragm and its pressure diaphragm which disconnects the thermostatic control under high temperature conditions.

- **James W. Light,** *Aeroproducts Operations of Allison Division, Dayton, Ohio, for an Actuator Control System and Valve Mechanism Therefor, No. 2,701,552, issued February 8.* This patent relates to control valve mechanism for a fluid pressure operated actuator having a reciprocable member and releasable locking means for preventing movement of the reciprocable member.

Mr. Light is an experimental engineer in the Engineering Department of Aeroproducts. He joined this organization in 1941 as a test operator. In 1943 he was promoted to a special tester and assumed his present position in 1945. He is, at present, engaged in developmental work on AAHL-A1 actuators (controls) and has previously done work on locking hydraulic actuators. Mr. Light attended Miami University and The Ohio State University. His work has resulted in several granted patents, including one on a propeller-speed controller and another on a biasing-type electronic synchronizer.

- **George R. Long***, *Frigidaire Division, Dayton, Ohio, for a Domestic Appliance, No. 2,701,837, issued February 8.* This patent relates to a deep-well cooker for an electric range. A crank-operated raising and lowering mechanism moves the surface heater to the top of the well for use as a conventional surface heater and to the bottom of the well for normal heating in the well.



- **Francis E. Sutter,** *General Motors Patent Section, Dayton, Ohio, for a Rubber Tire and Wheel Rim Therefor, No. 2,701,601, issued February 8.* This patent relates to a means for mounting a tire on a wheel rim. The tire is provided with a groove in the wall thereof which is adjacent the rim when the tire is in position. To hold the tire in place a wedging strip of resilient material is forced into the groove forcing the wall adjacent the groove against the rim to hold the tire in place.

Mr. Sutter is supervisor of the Drafting Department of the Patent Section's Dayton Office. In 1928 he joined the Delco Products Division's Inspection Department and one year later transferred to the Division's Patent Section as a patent draftsman. In 1942 he transferred to Inland Manufacturing Division as a layout draftsman for a nine-year period. Mr. Sutter attended Wittenberg College and University of Dayton.

- **Donald P. Worden,** *Rochester Products Division, Rochester, New York, for a High Frequency Welder, No. 2,701,833, issued February 8.* This patent relates to a high frequency welding device having rotary electrodes spaced by an air gap and forming a groove engaging the surface of a steel tube formed from a flat strip and having a seam which is welded. The surface of the electrodes which forms the groove is flattened at a plurality of points where it engages the tube to prevent rotation of the tube during welding.

Mr. Worden has served since 1951 as process engineer in charge of the Tubing Process Development Department, Rochester Products. He joined the Division in 1940 as a pipe fitter's helper in the Maintenance Department. He was transferred to the Electrical Department in 1942 and to his present Department in 1945. Mr. Worden has been granted two other patents in the field of electrical devices. He is affiliated with the American Institute of Electrical Engineers.

- **William J. deBeaubien,** *Pontiac Motor Division, Pontiac, Michigan, for an Illuminated Ash Tray, No. 2,702,338, issued February 15.* This patent concerns a lamp behind the instrument panel and a baffle on a slidable ash tray so arranged that when the ash tray is in partially open position, the baffle forms a downwardly directed floor and map light beam and, when the ash tray is fully open, the beam is cut off and the interior of the tray is illuminated.

- **William J. deBeaubien,** *Pontiac Motor Division, Pontiac, Michigan, for an Illuminated Ash Tray With Releasable Baffle, No. 2,702,339, issued February 15.* This patent relates to an illuminated ash tray in which a baffle is releasable from the ash tray so the ash tray can be removed from the instrument panel without removing the baffle.

Mr. deBeaubien is accessory engineer in Pontiac Motor's Engineering Department. Twenty-seven years ago he joined the Division as a co-op student from General Motors Institute. He was graduated from G.M.I. in 1932. During World War II Mr. deBeaubien was a service engineer—war products. He is a member of several technical societies and committees: the S.A.E. (which published his paper on automotive air conditioning with front-end system), the Engineering Society of Detroit, and the General Motors Heating, Ventilating, and Air Conditioning Subcommittee of the General Technical Committee.

- **Oscar V. Montieth,** *Allison Division, Indianapolis, Indiana, for a Brake for Propeller Drives, No. 2,702,100, issued February 15.* This patent relates to a brake for aircraft propellers released by a hydraulic cylinder supplied from either of two sources, the brake rotating many times more rapidly than the propeller and having a mechanical self-energizing feature actuated by reverse rotation of the propeller.

Mr. Montieth is chief development engineer in Allison's Production Design and Development Group. After earning the B.S. degree in electrical engineering from New Mexico College of Agriculture and Mechanic Arts in 1931, he joined the

Division as a test engineer. Mr. Montieth is co-author of a published paper on the "Torsional Vibration of In-Line Aircraft Engines." He is a member of the Institute of the Aeronautical Sciences, the National Advisory Committee for Aeronautics, and is past chairman of the S.A.E. committee on Aircraft Engine Vibrations.

• **David C. Redick,** *Delco-Remy Division, Anderson, Indiana, for a Direction Signal, No. 2,702,327 issued February 15.* This patent concerns a simplified direction signal switch mechanism wherein by-passing, cancelling, and overriding functions are performed by a single spring element.

Mr. Redick is staff engineer on ignition equipment in Delco-Remy's Engineering Department. He has been with the Division since he was employed as a blueprint boy in 1936. In 1948 he was made Model Shop foreman, promoted to switch engineer in 1949, to product engineer on jet engine components in 1951, and to his present position one year later. Mr. Redick attended General Motors Institute. His technical affiliations include membership in the Society of Automotive Engineers.

• **William H. Doerfner,** *Saginaw Steering Gear Division, Saginaw, Michigan, for a Valve Adapted for Hydraulic Power Steering Uses, No. 2,702,529, issued February 22.* This patent concerns a power steering control valve in which the movable component is a spool having oblique lands functional with respect to an inlet port, an exhaust port and a pair of power ports corresponding to the two ends of a double-acting fluid motor forming part of the power steering apparatus and coming into play at a predetermined steering resistance set by a centering spring. The oblique formation of the lands operates to smooth out the transmission from power steering to manual steering and vice versa.

Mr. Doerfner is general manager of Saginaw Steering Gear. He was appointed to this position in 1941. Mr. Doerfner was employed in 1919 as a timekeeper at the Saginaw Malleable Iron Division (later renamed Central Foundry Division). Five years later he transferred to Harrison Radiator Division as assistant superintendent of the foundry. In 1928 he returned to Saginaw Malleable Iron as works manager and in 1938 was promoted to general manager. Three years later he transferred to Saginaw Steering Gear in his present capacity. Mr. Doerfner is a member of the S.A.E.

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

• **Richard S. Gaugler,** *Frigidaire Division, Dayton, Ohio, for a Refrigerant Evaporating Means, No. 2,702,460, issued February 22.* This patent relates to evaporating means in which there is provided braided sleeving lining the evaporator tubing to cause liquid refrigerant to be kept in contact with all of the inner wall surfaces. This makes the entire wall surface effective for evaporation and prevents the flow of evaporated refrigerant from sweeping the walls bare of liquid.

Mr. Gaugler earned the B.S.Ch.E. degree from Purdue University in 1922 and was elected to the honorary society Phi Lambda Upsilon. He joined the GM Research Corporation, Dayton, in 1923 where he was made foreman of a pilot plant for blending ethyl fluid. In 1925 he transferred to Frigidaire Division as foreman-in-charge of process specifications and continued in this capacity until his transfer to the Engineering Department in 1940. Currently, he serves as supervisor of the major product line.

• **Ralph O. Helgeby,** *AC Spark Plug Division, Flint, Michigan, for a Combined Tachometer-Speedometer, No. 2,702,520, issued February 22.* This patent pertains to an instrument using concentric scales of different radii and a pointer indicating the transmission gear ratio selected and the vehicle speed in accordance with that ratio as well as the engine revolutions per minute.

Mr. Helgeby is an experimental engineer at AC Spark Plug. He started with General Motors as a speedometer designer at this Division in 1925. He holds a degree in mechanical engineering from Horten School of Technology (Norway) and studied business administration at General Motors Institute in 1926. One of Mr. Helgeby's most recent developments in speedometer design is the Redliner speedometer.

• **Arman J. Kearfott and Robert K. Williams,** *Research Laboratories Division, Detroit, Michigan, for a Method of Bonding Friction Material to a Support Member, No. 2,702,771, issued February 22.* This patent concerns a process for curing thermosetting resin material by immersing the material in a bath of water-emulsifiable oil heated to a temperature above the curing temperature of the resin and subsequently rinsing the oil from the cured article. It is particularly applicable to the bonding of brake linings to brake shoes.

Mr. Kearfott has served as assistant department head of the Research Laboratories' Electro-Chemistry Department since 1954. In 1920 he joined the Division as a tool maker, was promoted to research engineer in 1938, and transferred to his present Department in 1939. During his GM career, Mr. Kearfott has worked with rubber products, adhesives, plating, and plastics, and has served as a consultant on synthetic elastomers. He has been past chairman of various General Motors and S.A.E. and A.S.T.M. subcommittees on rubber, plastics, and adhesives.

Mr. Williams first joined the Research Laboratories as a member of the 1939 summer student program. Following his graduation from Princeton University in 1940, he returned to the Division as a college graduate-in-training. His early work was in the field of rubber and plastics. His more recent projects in the Fuels and Lubricants Department—of which he was appointed assistant department head in 1952—have been concerned with the mutual adaptation of engines, fuels, and lubricants.

• **Kurt Moritz and Hans F. Wagner,** *Adam Opel, Russelsheim/Main, American Zone, Germany, for a Screwed Plug for Closing Pipe Ends, No. 2,702,565, issued February 22.* This invention relates to a plug for preventing the entry of dirt into the flared end of a pipe having an internally threaded union nut. The plug comprises an inexpensive stamping having a conical sealing surface and an outwardly flared thread engaging rim.

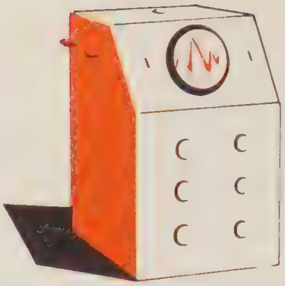
Mr. Moritz has served Adam Opel as chief refrigeration engineer since 1948. Mr. Moritz joined Adam Opel's Frigidaire Service Department in 1947. However, his nearly 28 years' experience with Frigidaire products started in 1928 when he joined the Frigidaire organization in Berlin as a sales engineer. Mr. Moritz received his engineering degree from the Technical University of Dresden in 1931. He is a member of V.D.I. (Society of German Engineers).

Mr. Wagner is assistant refrigeration engineer in Adam Opel's Frigidaire Engineering Department. He joined Adam Opel in 1933 as a parts designer in the Chassis Drafting Department. Since then, he has served as a layout man, senior layout man, liaison engineer, and project engineer for electrical equipment and instruments. Mr. Wagner received his engineering degree from Polytechnikum Arnstadt in 1924. He is a past member of the V.D.I.

- **Maurice A. Thorne and Roland V. Hutchinson,** *General Motors Engineering Staff, GM Technical Center, Detroit, Michigan, for a Vehicle Suspension, No. 2,702,701, issued February 22.* This patent concerns a double torsion bar construction, one operating independently for light loads, and both operating together for heavy loads to insure a smooth ride under all load and road conditions.

Mr. Thorne has been engineer-in-charge of the Vehicle Development Group of the Engineering Staff since 1952. He joined the Engineering Staff in 1941 following seven years with the Oldsmobile Division Engineering Department. During World War II, Mr. Thorne was chief engineer on the heavy tank M-26 and related pilot models at Fisher Tank Division. He received the B.A. degree from George Washington University in 1922. He is a member of the Society of Automotive Engineers.

Mr. Hutchinson has served as engineer-in-charge of the Automotive Ordnance Section of the Engineering Staff's Vehicle Development Group since 1952. He joined General Motors in 1919 as assistant to the chief mechanical engineer at Dayton Metal Products, forerunner of Research Laboratories Division. Part of his career, however, was spent on various engineering assignments with Oldsmobile Division. He is a member of the S.A.E., the A.S.M., and serves as an alternate member on the Research and Development Board of the Engine-Fuel Committee of the Army.



- **Ross W. Buchanan, Dr. Robert W. Smith, and Taine G. McDougal,** *AC Spark Plug Division, Flint, Michigan, for a High Ohmic Resistance Conductor, No. 2,703,356, issued March 1.* This patent concerns a process for making resistance cables wherein fibrous material is impregnated with a suspension of finely divided conducting material, dried, and then immersed in boiling water to fix the conductive particles to the fibers. After the material is again dried, an insulating coating may be applied.

Mr. Buchanan is supervisor of chemical research at AC Spark Plug. He was appointed to his present position in March 1955, twenty-two years after joining the Division as a routine chemist. Mr. Buchanan received the B.S. degree from Michigan State College in 1932. His projects at AC have covered development of oil filter materials and synthetic organic coatings. Mr. Buchanan is a member of Tau Beta Pi and his technical affiliations include membership in the American Chemical Society, American Electroplaters Society, Electrochemical Society, and Society of Automotive Engineers.

Dr. Smith serves as supervisor of physical and metallurgical research at AC Spark Plug, where he is currently engaged in the development of new ceramic resistors for spark plugs and automotive instruments. He holds the B.S. degree in physics from University of Chattanooga (1929) and the Ph.D. degree, also in physics, from University of Michigan (1933). Dr. Smith's research in the field of spark plug and electrical instrument design has resulted in eight patents and four published papers on spectrographic-analysis topics. He is a member of the American Society for Metals, A.I.E.E., Optical Society of America, American Association for the Advancement of Science, American Physical Society, and A.S.T.M.

At the time of his retirement in September 1954, **Mr. McDougal** was director of research and spark plug engineering at AC Spark Plug. He received the ceramic engineering degree from The Ohio State University in 1911. In 1914 he was employed by AC Spark Plug as a ceramic engineer. Mr. McDougal's work with spark plugs, spark plug insulator compositions, drying and firing apparatus, and synthetic jewel bearings resulted in over 40 patents and a published paper on the casting of clay wares. He is a Fellow of the American Ceramic Society and is a member of Sigma Xi, Sigma Delta Chi, and the S.A.E.

- **Lawrence P. Brissette and John G. Haviland,** *Fisher Body Division, Detroit, Michigan, for a Compression Tester, No. 2,703,492, issued March 8.* This invention covers a portable machine for testing the compression of foam rubber specimens comprising a loaded beam having a specimen-engaging foot and an indicator to measure deflection of the beam.

Mr. Brissette is a layout draftsman in the Experimental and Development Section of Fisher Body. In 1946, after two and one-half years of military service, Mr. Brissette joined Fisher Body's Central Engineering Activities Department as a General Motors Institute co-op student. In 1951 he received the B.M.E. degree from the Institute. This is the first patent which resulted from his work with automobile body seat padding testing. The last three years he has been concerned with the development of power seat adjusters, vertical seat adjusters, power window lifts, and electric convertible-top lifts.

Mr. Haviland serves as senior project engineer in Fisher Body's Experimental and Development Section. He holds both the B.S.E. degree (1937) and the M.S. degree (1939) in chemical engineering from University of Michigan. In 1939 Mr. Haviland was employed as a chemist in Fisher Body's Laboratory. In 1947 he was made senior project engineer—his present position. This patent resulted from his current work on seat cushions and new materials.

Mr. Haviland is a member of the Body Activity Committee of the S.A.E.

- **Engelbert A. Meyer,** *Fisher Body Division, Detroit, Michigan, for a Switch Housing Retaining Means, No. 2,703,662, issued March 8.* This patent relates to a sheet-metal retainer for supporting insertable elements, such as switches for electrically operated automobile windows.

Mr. Meyer is senior project engineer in the Central Engineering Department of Fisher Body. Following his employment with this Division in 1935, he was assigned as a tracer, progressing to detailer, engineer, design engineer, project engineer and, subsequently, to his present position of senior project engineer (1943). His work on automotive snap attachments has resulted in five patents.

- **Clarence H. Jorgensen* and Lawrence C. Dermond,** *Rochester Products Division, for a Cigar Lighter, No. 2,704,318, issued March 15.* This invention relates to a cigar lighter for automobiles, including a manually resetting, automatic circuit breaker for opening the circuit upon overheating of the heating element.

Mr. Dermond has served since 1948 as senior research engineer in Rochester Products' Engineering Department. He entered the General Motors organization in 1934 in the position of draftsman and layout with Delco-Remy Division. In 1944 he transferred to Rochester Products as senior engineer. Mr. Dermond attended Purdue University and Tri-State College. His technical affiliations include membership in the Society of Automotive Engineers.

- **Peter Mushovic,** *Moraine Products Division, Dayton, Ohio, for a Method for Separating Composite Aluminum-Iron Articles, No. 2,704,249, issued March 15.* This patent is directed to a method for reclaiming aluminum alloys from scrap composite articles including the aluminum alloy coextensively bonded to a steel backing member and comprises embrittling the bonding area by heating the articles and then breaking the aluminum off the steel by mechanical means.

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

Mr. Mushovic serves as senior process engineer in Moraine Products' Processing Department. His first position with the Division was as a routine metallurgist in its Engineering Department, directly after earning the B.S. degree in metallurgical engineering from Missouri School of Mines and Metallurgy (1944). Six years later he was promoted to production engineer and in 1954 was promoted to his present position. This patent was granted as a result of Mr. Mushovic's work with developing a method for cladding aluminum to steel. After completion of this project he set up the processing and production operations for power brake units. Mr. Mushovic is a registered professional engineer, State of Missouri.

- **Hans O. Schjolin and Donald K. Isbell,** *GMC Truck & Coach Division, Pontiac, Michigan, for a Wheel Bearing Adjustment, No. 2,704,233, issued March 15.* This patent relates to a wheel bearing structure substantially enclosed by a brake structure on the outboard end of the axle with an adjusting device being provided to adjust the bearing structure from the outboard side of the brake structure.

Mr. Schjolin has served as a new development engineer in GMC Truck & Coach's Engineering Department since 1937. He was originally employed in 1923 as a draftsman by Yellow Truck & Coach Manufacturing Company, Chicago. Mr. Schjolin graduated from Karlstad College in Sweden in 1920, and from Mitweida College, Germany, in 1923. His work has resulted in several patents and published papers.

Mr. Isbell has served as senior engineer in GMC Truck & Coach's Engineering Department since 1947. He was employed as a draftsman in this Department in 1936. In 1943 he was made layout man and promoted to senior layout man one year later. At present, he is concerned with the development of new vehicle drive units. This patent was filed during his work with torque converters and brakes.

Progress Reports from GM Locations

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Braking Improvements Increase Highway Safety for GMC Trucks, Coaches

RECENT engineering improvements in the braking system for trucks and buses by GMC Truck and Coach Division engineers have resulted in shortening the stopping distances after emergency application of the brakes. The improvements result from the continual developmental work carried out in an effort to reduce the time interval between driver reaction and full-pressure application of the brakes at the vehicle's wheels.

The time now required for braking application at the vehicle's wheels, after depression of the brake pedal, is approximately two-tenths of a second. For example, the full-pressure air brake application time for a GMC 4-wheel tractor hauling a tandem-axle semi-trailer has been cut from 0.31 sec to 0.23 sec on the rear axle of the tractor. On a 41 passenger GMC coach the time interval has been shortened from 0.42 sec to 0.16 sec on the rear wheels and from 0.39 sec to 0.18 sec on the front wheels.

The decrease in the time interval has been accomplished by streamlining the air-brake fittings, elimination of sharp angles and crimping in the brake system tubing, use of special valves having no restrictions, and applying tubing of sufficient size so that the flow of air under pressure will not be impeded.

An increase in the efficiency and life of the mechanical component parts of the brake system also has resulted from the developmental work. Significant progress has been made in brake drum construction as a result of using new metal alloys which have higher heat dissipation qualities and more strength. The new brake drums are less susceptible to deflection and distortion under high pressures and temperatures. Improvement also has been made in brake camshafts so that there is now less deflection and better transmission of braking power.

A Typical Problem in Engineering:

Determine the Interference Fit and Resulting Stresses in the Design of a Cold Extrusion Die

By CHARLES R. BRADLEE
Process Development
Section

Assisted by Robert W. Bund
General Motors Institute

Solve a problem in cylinder wall stresses to find an economical die design

The problem of limiting stresses in mechanical components is a common one frequently associated with structures and machines. Stress problems of this type often are found in tool design. A typical example is the determination of an interference fit in the design of a cold extrusion die to produce piston pins from low-carbon steel. The solution to this problem will be presented in the September-October 1955 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

Techniques for cold forming metals (variously termed cold working and cold extrusion) have received considerable attention in recent years and many are in use as manufacturing processes. Cold forming can be defined as the plastic working of metal under compressive stress and at a temperature well below the re-crystallization point. The process is characterized by very high stresses in the work and tools, especially when the work piece is steel. The problem presented below is an actual one and typical of what might be encountered in the design of a die for a "cupping" or backward extrusion operation on a mild steel slug.

In planning the manufacture of piston pins, several alternate methods may be used. The cold extrusion process is one method which must be considered. It starts with a slug of lubricated steel, slightly smaller in diameter than the finished part and of the required volume. The slug is introduced into a die and squeezed from both sides by punches (Fig. 1). Metal is forced to flow back through the annular space between each punch and the die as the punches advance. The pressure required to induce this flow may reach 300,000 psi or higher directly under the punches. At such pressures the metal flows plastically but is restrained from radial movement by the die cavity.

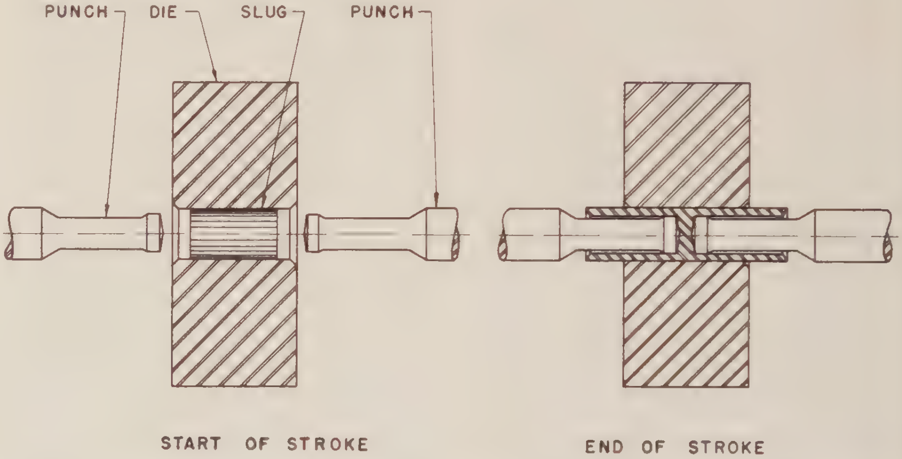

Fig. 1—This sketch illustrates the application of the cold extrusion process to the forming of a piston pin from a lubricated slug.

Just what percentage of this extrusion pressure will be transmitted to the die walls and experienced as a radial pressure is difficult to predict; however, experience offers ample evidence that the radial pressure in a case such as the piston pin application in this problem is approximately 100,000 psi. It can be readily appreciated that this pressure requires very thick die walls. Stresses, therefore, cannot be predicted by conventional thin-wall formulae and the problem is reduced essentially to the design of a heavy-wall cylinder to contain high internal pressures.

In order to limit the maximum working tensile stress at the bore, dies are customarily made of two or more cylinders shrunk or pressed together. Such an arrangement places the inner cylinder under an external pressure and the outer cylinder under an internal pressure. Fig. 2c graphically illustrates the initial stress distribution in such an assembly. When a double-wall cylinder is subjected to an internal working pressure the stress pattern across the wall becomes that shown in Fig. 2d and is the algebraic sum of stresses shown in Fig. 2a and 2c. Stress at the cylinder bore is limited in this manner to values compatible with available tool materials. This principle has been applied for many years to the design of cannon and high-pressure vessels. Carbide wire draw dies and some header dies also are constructed in this manner.

The high strength requirements coupled with a need for resistance to the wear of the work piece metal as it flows between the punch and die require the use of tool steel for the punch and the inner ring of the die. The outer die ring requires material with excellent strength properties but only average wear resistance.

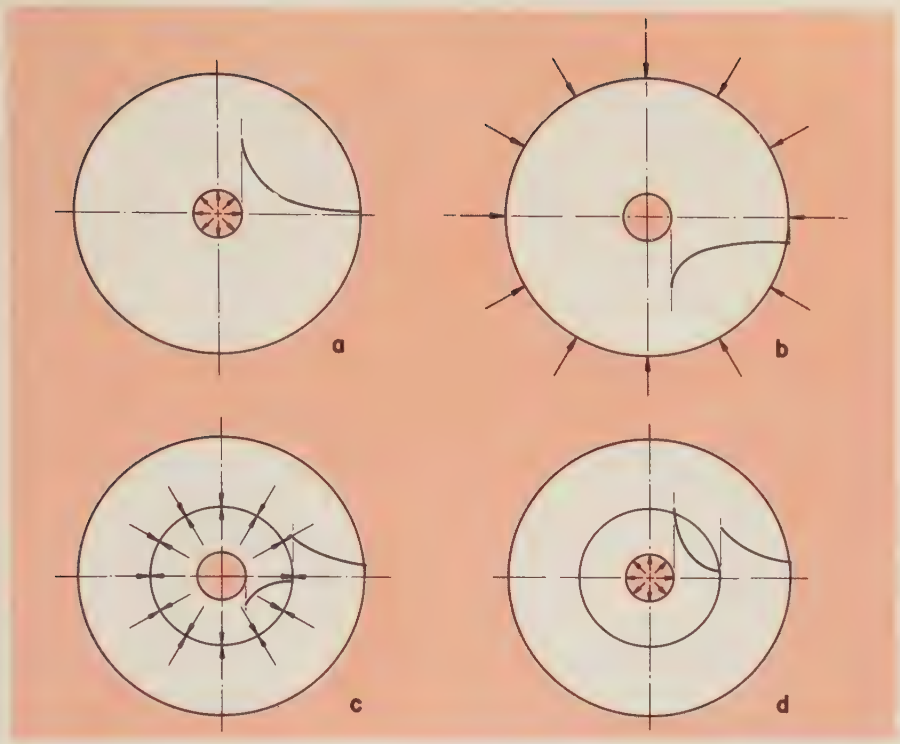

Fig. 2—Graphical representations can be made of the stresses resulting from interference fits between two-walled cylinders as well as heavy-wall cylinders and the additional stresses resulting from internal and external pressures. Fig. 2a represents the stress pattern in a cylinder subjected to internal pressure only. Fig. 2b represents a stress pattern in a cylinder subjected to external pressure only. Fig. 2c represents a stress pattern in inner and outer cylinders resulting from an interference fit at the mating surfaces. Fig. 2d represents a stress pattern in a double-wall cylinder (as in Fig. 2c) resulting from internal pressure, as well as an interference fit in assembly.

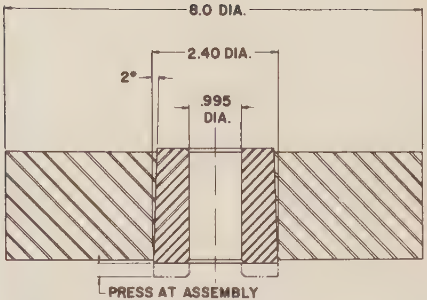

Fig. 3—The principal dimensions and conditions established for the double-wall cylinder are shown above. The problem is to calculate the dimension *press at assembly* which will give an initial bore stress of —100,000 psi.

Various solutions are available for the cylinder wall stress problem, each based on one of the various failure theories. Each solution finds application to some limited area of the general problem but, for heavy-wall cylinders, results predicted by the maximum strain theory have been found by experience to be the most reliable. It is upon this theory, therefore, that the solution to this type of problem is based. The general solution to the problem takes the form (Birne's equation for an open-end cylinder):

$$S_t = (1 - m)a + \frac{(1 + m)b}{r^2}$$

where

S_t = equivalent tangential stress

$a = [P_i d_i^2 - P_o d_o^2]/(d_o^2 - d_i^2)$

$b = (d_i^2 d_o^2/4)\,[(P_i - P_o)/(d_o^2 - d_i^2)]$.

Fig. 2a illustrates graphically the induced tangential stress distribution across a heavy-wall cylinder subject to internal pressure only and Fig. 2b illustrates a cylinder subject to external pressure only. Fig. 2a may be considered representative of the working stress induced by radial pressure during extrusion. Note the high value of stress at the bore and the manner in which it rapidly diminished near the outside diameter *OD*.

Problem

The problem presented is one which would be encountered in the design of tooling for the manufacture of extruded piston pins. Certain limiting conditions exist around which the design must be made. The fixed conditions are (Fig. 3):

- Finish bore diameter (fixed by part size) = 0.9950 ± 0.0005 in.
- Die OD (limited by die space available) = 8.0 in.

There is, of course, some optimum design relating to the above dimensions and to such factors as the material selected. In practice, however, this design is not critical and certain constants can be applied with assurance that results will be satisfactory. The following conditions and dimensions, therefore, can be derived:

(a) A double wall cylinder is to be employed (Fig. 3).
(b) The interface diameter is to be 0.3 times the OD or 2.40 in.
(c) The inner and outer sections are to be tapered 2° per side on the mating faces to permit a press assembly.
(d) The inner ring is to be made of an O-1 (oil hardening) tool steel at a hardness of 60-62 Rockwell C.
(e) The outer ring is to be made of S.A.E. 4340 steel.

Having established the two fixed conditions and the five derived conditions, the following problem remains:

(a) Calculate the distance the two die sections must be pressed together to obtain an initial bore stress of − 100,000 psi.
(b) Assuming the tensile strength of a steel can be approximated by the formula: *Tensile strength = 500 × Brinell hardness number*, what hardness must be specified for the outer ring to insure a safety factor of 2 when the working pressure at the bore is 150,000 psi?

The following suggestions are offered for the solution of the problem. Use Birne's equation[1] for open cylinders and Timoshenko and Lessell's equation[2] for the pressure between shrink or press assembled cylinders to calculate stresses and pressures.

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1. Vallance, Alex and Doughtie, V. L., *Design of Machine Members* (New York: McGraw-Hill Book Company, Inc., 2nd Edition, 1943).

2. Eshbach, Ovid W., *Handbook of Engineering Fundamentals* (New York: John Wiley and Sons, Inc., 1936).

Other related literature in this field includes the following:

Seely, Fred B. and Smith, James O., *Advanced Mechanics of Materials* (New York: John Wiley and Sons, Inc., 2nd Edition, 1952).

Timoshenko, Stephen, *Strength of Materials* (New York: VanNostrand, Volume 2, 2nd Edition, 1940-'41).

Solution to the Previous Problem:

Determine the Shear Loads and Bending Moments in a Statically Indeterminate Beam

By **HAROLD E. HELMS**
Allison
Division

Before a design engineer can satisfactorily select the geometry and material of a structure he must first analyze the forces acting upon it to determine the shear loads and bending moments. When the structure is statically indeterminate the analysis becomes somewhat more involved because basic equations of statics are not sufficient to determine all of the unknown forces. This is the solution to the problem presented in the May-June 1955 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

The critical section is determined; the material and shape can be selected

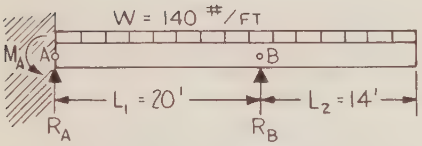


Fig. 1—In the analysis of indeterminate beams, the equations of statics are not sufficient to find all the unknowns. The resisting moment M_A acting on the fixed end of the above beam can only be determined by the application of a strength of materials deflection equation.

THE determination of unknown forces and stresses in a statically indeterminate beam requires the use of strength of materials formulae, in addition to the basic equations of statics.

Fig. 1 shows the uniformly loaded, statically indeterminate beam which was presented for analysis. The beam has a fixed end and is supported at a distance L_1 from the left end. Before the shear loads and bending moments can be determined, there are three unknowns which must be found—the vertical reactions R_A and R_B at the supports and the moment M_A acting on the beam at point **A**.

Since there are no horizontal forces, only two equations of statics, $\Sigma M = 0$ and $\Sigma V = 0$, exist for the determination of unknown forces acting on this beam. Since there are three unknowns, these two equations are not sufficient to calculate the unknown reactions and moment. If the condition is established, however, that the deflection at points **A** and **B** on the beam is zero, it is then possible to determine the unknown moment M_A by the fundamental strength of materials second area-moment proposition for beam deflection.

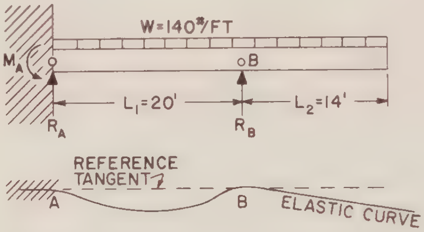


Fig. 2—The condition that the deflection of the beam at points **A** and **B** is zero makes it possible to calculate M_A by the second area-moment proposition.

The determination of M_A will make the beam statically determinate. This will allow the use of the two applicable equations of statics to determine the reactions R_A and R_B and, in turn, the determination of the shear loads and bending moments to which the beam is subjected. Fig. 2 shows the approximate shape of the beam's elastic curve with zero deflection at points **A** and **B**.

The second area-moment proposition, as applied to the beam in Fig. 2, states that the vertical displacement y of point **B** from the reference tangent to the elastic curve at **A** equals the moment, with respect to point **B**, of the area A_M of the moment diagram between **A** and **B** times the distance $\bar{x}$ from point **B** to the centroid of the moment diagram area divided by E, the modulus of elasticity of the beam material, times I, the moment of inertia of the beam. Keeping in mind that the displacement y of point **B** is zero, the second area-moment proposition can be expressed by the following equation:

$$y = A_M\bar{x}/EI = 0. \qquad (1)$$

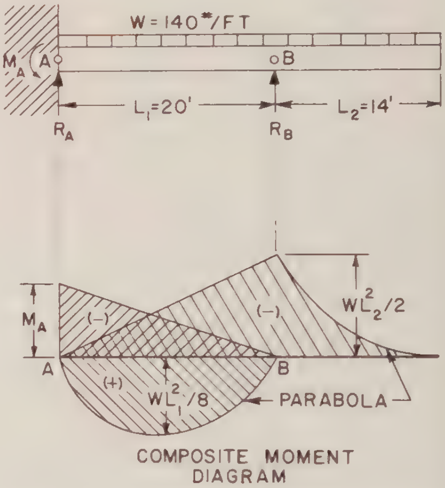


Fig. 3—The calculation of the resisting moment M_A by the second area-moment proposition is facilitated by drawing a composite moment diagram which shows the moments caused by the uniform load and the resisting moment M_A.

Fig. 3 shows an approximate composite moment diagram resulting from the uniform load and the forces to which the beam is subjected. This diagram is needed to conveniently determine the areas and centroids which are necessary for insertion into equation (1) to calculate the moment M_A. Referring to Fig. 3 the following equation, based on equation (1), can be written, keeping in mind that A_M is the area of the moment diagram between points **A** and **B** and that $\bar{x}$ is the distance from point **B** to the centroid of each of the moment diagram areas in question:

$$\tfrac{1}{2}(M_A)(L_1)\tfrac{2}{3}(L_1) + \tfrac{1}{2}(wL_2^2/2)(L_1)(L_1/3) - \tfrac{2}{3}(wL_1^2/8)(L_1)(L_1/2) = 0.$$

Simplifying

$$M_A L_1^2/3 + wL_1^2L_2^2/12 = wL_1^4/24$$
$$M_A = w(L_1^2 - 2L_2^2)/8. \qquad (2)$$

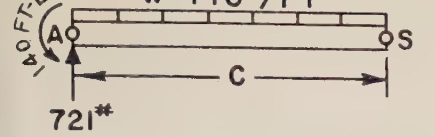


Fig. 4—To determine the location of zero shear on the beam, the section of the beam between points **A** and **S** is treated as a free body. The point **S** denotes the location of zero shear which is at a distance *C* from point **A**.

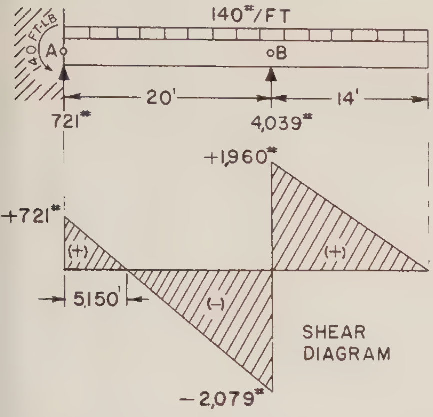


Fig. 5—The shape of the shear diagram indicates that there is a point of maximum positive bending moment at a distance of 5.150 ft from point **A**. The diagram also shows that the point of maximum shear occurs at point **B**.

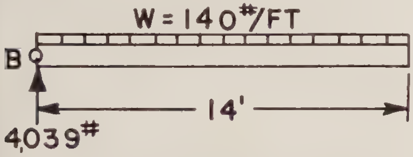


Fig. 6—To determine the bending moment at point **B**, the section of the beam to the right of this point is taken as a free body.

Substituting in equation (2) the known values for w, L_1, and L_2 gives

$$M_A = 140[20^2 - 2(14)^2]/8$$
$$M_A = 140 \text{ ft-lb.}$$

The determination of M_A makes the beam statically determinate. It now is possible to use the basic statics equation $\Sigma M = 0$ to calculate the reaction forces R_A and R_B.

The reaction force R_A can be calculated by a summation of moments about point **B** as follows (clockwise moments positive):

$$\Sigma M_B = 0$$
$$20R_A - 140 - 140(34)\ (3) = 0$$
$$R_A = 721 \text{ lb.}$$

The reaction force R_B can be calculated by a summation of moments about point **A** as follows (clockwise moments positive):

$$\Sigma M_A = 0$$
$$(140)(34)(17) - 140 - 20R_B = 0$$
$$R_B = 4{,}039 \text{ lb.}$$

The value for R_A establishes the shear load at point **A** on the beam. Referring to Fig. 1 it can be seen that the shear at point **A** is 721 lb upward. (Upward forces will be considered as positive shear.) The total reaction force at point **B** is 4,039 lb. The shear infinitely close to the left of the reaction R_B will be equal to 721 − 140(20) or −2,079 lb. The shear infinitely close to the right of reaction R_B will be equal to 721 − 140(20) + 4,039 or + 1,960 lb.

The establishment of the negative shear of 2,079 lb at point **B** indicates that there is a point between **A** and **B** where the shear load is zero. (It is realized, of course, that the shear at the free end of the beam is zero). To determine the location where the shear load is zero, the section of the beam to the right of point **A** can be treated as a free body (Fig. 4).

Referring to Fig. 4, *C* represents the distance from point **A** to the location of zero shear, point **S**. The distance *C* can be evaluated by a summation of all vertical forces acting on the free body as follows:

$$\Sigma V = 0$$
$$721 - 140(C) = 0$$
$$C = 5.150 \text{ ft.}$$

The determination of the shear loads at points **A** and **B** and the location on the beam where there is zero shear define the shape of the required shear diagram (Fig. 5).

To determine the bending moment at any point along the length of the beam, the summation of forces times their respective lever arms to either the right or left of the point will give the moment at that location.

The bending moment at point **A** has already been established as + 140 ft-lb. To calculate the bending moment at point **B**, the section of the beam to the right of this point can be taken as a free body (Fig. 6). A summation of moments about point **B** will give the following value for M_B, the bending moment at point **B**:

$$\Sigma M_B = 0$$
$$M_B = 140(14)(7)$$
$$M_B = +\ 13{,}270 \text{ ft-lb.}$$

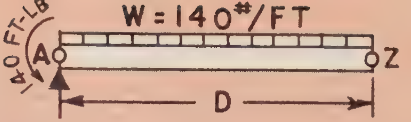


Fig. 7—To determine the location of zero bending moment, the section between points **A** and **Z** is taken as a free body. Point **Z** is the location of zero moment located a distance *D* from point **A**. A summation of moments about point **Z** gives the distance *D*.

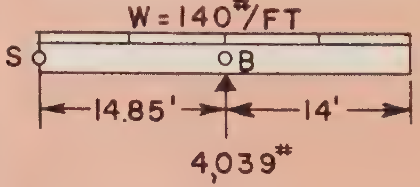


Fig. 8—To calculate the bending moment at point **S** on the beam, the section of the beam to the right of point **S** is taken as a free body and a summation of moments about **S** is made.

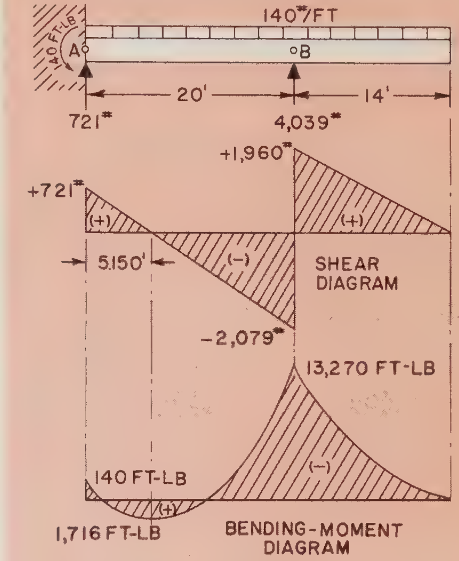


Fig. 9—The shear and bending moment diagrams completely define the loadings on the beam and permit rigorous stress analysis at any location in its length. Point **B** is the locaton of the beam's critical loading point.

To determine the location of zero bending moment, the section of the beam to the right of point **A** can be used as a free body (Fig. 7). Referring to Fig. 7, *D* designates the distance from point **A** to the location of zero bending moment, point **Z**. The distance *D* can be evaluated by a summation of moments about point **Z** as follows (clockwise moments positive):

$$\Sigma M_Z = 0$$
$$721(D) - 140 - 140(D)(D/2) = 0$$
$$721D = 140 + 70D^2.$$

Dividing the above equation through by 70 and setting it equal to zero gives

$$D^2 - 10.3D + 2 = 0. \qquad (3)$$

Examination of equation (3) shows that it is a quadratic and can be solved by the quadratic formula as follows:

$$D = \left[-(-10.3 \pm \sqrt{(-10.3)^2 - 4(1)(2)}\right]/2 \quad (1)$$
$$D = \left[10.3 \pm \sqrt{98.09}\right]/2$$
$$D = \left[10.3 \pm 9.904\right]/2.$$

Therefore,

D = 10.102 ft and 0.198 ft, which are both points of zero bending moment to the right of point A.

In the previous calculations for shear loads on the beam it was determined that there was zero shear at a distance of 5.150 ft to the right of point A. This point represents a location of maximum positive bending moment. This maximum positive bending moment (positive bending moment gives tension stress in the lower fibers and compression stress in the upper fibers of the beam) can be calculated by a summation of moments to the right of the location of zero shear, point S. Treating this section of the beam as a free body (Fig. 8), the following moment equation can be written (clockwise moments negative):

$$\Sigma M_S = 0$$

$$M_S = (+4{,}039)(14.85) - 140(28.850)(14.425)$$

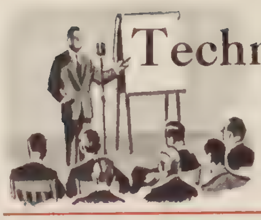
$$M_S = +1{,}716.6 \text{ ft-lb.}$$

The determination of bending moments at points A, B, and S and the establishment of the points where zero bending moment occurs define the shape of the required bending-moment diagram (Fig. 9).

Summary

An examination of the shear and bending-moment diagrams shows that the critical section of the beam is at point B. The maximum shear load (P = 2,079 lb) and the maximum bending moment (M = 13,270 ft-lb) at this point can be substituted directly into the average shear stress and bending stress equations $S = P/A$ and $S = Mc/I$. The values for A (beam cross sectional area), c (one-half of the beam's depth), and I (moment of inertia of the beam) which are selected determine the geometry of the beam. The stresses which are then evaluated determine the beam material to be used.

With a few stress calculations, therefore, and considerations of such factors as methods of fabrication, cost, and material availability the design engineer can properly select the geometry and structural material of a beam which will satisfactorily withstand the loads to which it is subjected.



Technical Presentations by GM Engineers

Speaking appearances by General Motors engineers further the objective of making available to the public current information about GM engineering developments. Participation includes presentations of technical papers, lecturing before college engineering classes, and serving as panel members at symposium-type meetings. A list of some of the recent speaking engagements, presented below, typifies the variety of appearances made by engineers from GM Divisions and Staffs, and likewise indicates the wide range of engineering topics discussed.

Aircraft Engines

As part of the Wright Air Development Center Symposium on Laboratory Evaluation of Gas Turbine Lubricants, April 5, **M. C. Hardin**, senior project engineer—turbine components in the Aircraft Engines Operations of Allison Division, presented the paper "Lubricant Requirements of the Turbo-Prop Engine."

Two Allison engineering personnel participated in the Society of Automotive Engineers' Aeronautic Meeting, held in New York City on April 18. **C. E. Mines**, chief—engineering services, Aircraft Engines Operations, talked on "The Challenge of Cooperative Engineering in the Jet Age" as part of a panel on aeronautical standards; **J. B. Wheatly**, assistant chief engineer—development—power turbines, Aircraft Engines Operations, described "The Allison T56 Turbo-Prop Aircraft Engine."

Automotive Engines

Willard R. Houser, supervisor of the Dynamometer Department, AC Spark Plug Division, participated in the Annual Conference of the Canadian Automotive Electric Association, held in Hamilton, Ontario, on March 7. He presented the paper "The Spark Plug as an Integral Part of Internal Combustion Engines."

On March 24, during the Richfield Oil Corporation Distributors' Convention held in Atlantic City, New Jersey, **Martin J. Caserio**, chief engineer in AC Spark Plug's Automotive Engineering Department, outlined "Future Engine Design Trends in Relation to Fuels and Lubricating Oils."

Clayton B. Leach, on April 27, described "What You Should Know to Design an Automotive Engine" to the Student Chapter of the S.A.E. at Stevens Institute of Technology in Hoboken, New Jersey. Mr. Leach is assistant chassis engineer in Pontiac Motor Division's Product Engineering Department. During the May 11 meeting of the Division of Refining, American Petroleum Institute, held in St. Louis, Missouri, **J. P. Charles**, assistant chief engineer in the same Department, presented a discussion of the CFR (CRC) paper on "Vapor Lock and Hot Stalling."

Automotive Engineering

A meeting of the Auto Maniacs of America held in the Veteran's Memorial Building, Detroit, Michigan, on March 26, was the occasion for a talk by **C. M. Rubly**, assistant staff engineer, Passenger Car Chassis Design Department, Chevrolet Motor Division. Mr. Rubly discussed "The Construction of the 1955 Passenger Car Chassis."

Walter Mackenzie, liaison engineer in Chevrolet Motor's Engineering Department, addressed the Michigan Chapter of the American Marketing Association on April 11. The title of his talk, given at University of Detroit, was "New Product Development."

Another of Chevrolet Motor's engineering personnel, **Mauri Rose**, special engine and vehicle development engineer stationed at the GM Proving Ground in Milford, Michigan, discussed "Horsepower and People" before the Vandalia

Lions Club. The meeting was held in Dayton, Ohio, on April 14.

"Automobile Air Conditioning Component Capacity Design and Application" was outlined by **L. A. Zwicker,** assistant chief engineer, Product Engineering Department, Harrison Radiator Division, before the April 14 meeting of the Chicago Section of the American Society of Refrigerating Engineers.

Kenneth W. Gage, chief engineer of Detroit Transmission Division, described "The Development and Application of the Hydra-Matic Transmission" during the April 19 meeting of the Plymouth, Michigan, Kiwanis Club.

At a joint meeting of the Rochester and the Buffalo, New York, Sections of the S.A.E., held on April 19, **Kenneth A. Stonex** spoke on "The Design and Performance Trends in Present and Future Automobiles." Mr. Stonex is head of the Technical Data Department of the General Motors Proving Ground at Milford, Michigan.

A meeting of the American Industrial Hygiene Association in Buffalo, New York, on April 24, was the occasion for a talk by **F. A. Patty,** department head, **V. J. Castrop,** assistant department head, and **J. F. Stephen,** industrial hygienist—all of the Research Laboratories Division's Industrial Hygiene Department. The title of the joint presentation was "Comparison of Carbon Monoxide Concentrations in Detroit and Los Angeles."

Howard K. Gandelot, engineer-in-charge of the Vehicle Safety Section of the General Motors Engineering Staff, addressed the 3rd Annual Michigan Driver Education Conference, held at University of Michigan on April 30. The title of his talk was "Automotive Design for Safety." On May 12 Mr. Gandelot described "The Shape of Things to Come" as part of the 7th Annual Oklahoma Safety Conference, held in Oklahoma City.

"The Ride and Handling of Today's Cars" was the subject of **S. P. Malone's** talk during the Central Pennsylvania Section of the American Society of Mechanical Engineers meeting at Pennsylvania State College on May 3. Mr. Malone is a staff engineer in the Shock Absorber Section of Delco Products Division.

Sherrill Richey, staff engineer in Chevrolet Motor's Accessory and Electrical Design Group, and **Harold O. Flynn,** staff engineer in the Division's Truck Chassis Design Group, spoke on "A Carriage for Milady" before the Mid-Michigan Section of the S.A.E. The meeting was held in Saginaw, Michigan, on May 9.

Before the Baltimore-Washington Branch of the A.S.R.E. meeting in Baltimore, Maryland, on May 10, **Webster J. Owen** described "1955 Automobile Air Conditioning Systems." Mr. Owen is an assistant staff engineer in the Heating and Air Conditioning Department of Cadillac Motor Car Division.

Z. Arkus-Duntov, research development engineer in Chevrolet Motor's Vehicle Development Group, outlined "The Suspension and Chassis Design Problems Associated with High Speed, High Performance Cars" before the Texas Section of the S.A.E., meeting in Dallas on May 20.

Buses and Off-the-Road Vehicles

On February 9 **Olin A. Lee,** district sales manager for Euclid Division, presented a seminar on logging engineering to the senior class in logging engineering at the College of Forestry, University of Washington, Seattle. On February 10 Mr. Lee gave the same talk to the junior class, coupled with a field trip.

Alan S. McClimon took part in the Sixteenth Annual Highway Conference held at University of Utah from March 7 to 9. Mr. McClimon, manager of sales development at Euclid, outlined "Twin Power Crawler Tractor Development."

"Air Suspension" was the subject discussed by **Donald J. LaBelle,** engineer on structures and suspensions in the New Development Department of GMC Truck & Coach Division, at the April 12 meeting of the St. Louis Section of the S.A.E.

On May 10 **Floyd A. Franklin** talked on "Two-Level Intercity Coaches" before the Chicago Section of the S.A.E. Mr. Franklin is a coach engineer at GMC Truck & Coach.

Requests may be directed to the Educational Relations Section for assistance in obtaining the services of GM engineers to speak before engineering classes or other student groups.

Electronics

On March 17 **Gerald R. Broshar** gave a presentation entitled "Development of the Guide Autronic Eye Automatic Headlamp Control" before the Central Indiana Chapter of the Society of Professional Engineers meeting in Indianapolis. Mr. Broshar is a field engineer in the Engineering Department of Guide Lamp Division.

"Electric Safety Controls for Industrial Gas-Fired Special-Atmosphere Furnaces" was the subject of the paper given by **Charles E. Huggins,** control engineer in the Electrical Processes Department of Delco Products, before the American Institute of Electrical Engineers meeting in Dayton, Ohio, on April 13.

Two of Delco Products' engineering personnel served as panel members for a discussion on "Joint Industry Conference Standards" before the A.I.E.E. meeting in Dayton on April 27. The two men were: **George A. Neyhouse,** supervisor of the Engineering Electrical Laboratory, and **William R. Ringo,** process engineer in the Equipment and Methods Department.

C. J. Votava spoke on "Duties and Responsibilities of the Electrical Engineer in the Automotive Radio Industry" at a meeting of electrical engineering students at Rose Polytechnic Institute, Terre Haute, Indiana. Mr. Votava, who spoke on May 5, is a senior project engineer in the Engineering Department of Delco Radio Division.

Robert B. Colten, senior project engineer in charge of the Electronics Department, Process Development Section, General Motors Manufacturing Staff, discussed "Electronics as a Manufacturing Tool" at a meeting of the University of Michigan Masters Club, held in Ann Arbor on May 13.

General Engineering

Speaking before a group of engineers interested in the construction of service stations, February 24, **M. M. Roensch,** director of laboratory tests, Experimental Engineering Department, Chevrolet Motor, spoke on "Servicing the Automobile of Tomorrow." The meeting was held in Granville, Ohio.

James H. Smith, general manager, Central Foundry Division, spoke at the Annual Conference of the Foundry Educational Foundation which was held in Cleveland, Ohio, March 9. The title of his address was "Molding Your Future."

Two Chevrolet Motor engineers — **Maurice Olley,** director of the Research and Development Section, and **J. B. Burnell,** design engineer—addressed engineering groups March 16. Mr. Olley spoke at the Golden Anniversary meeting of the Toronto, Canada, Section of the S.A.E. His subject: "Future Possibilities and Trend in Passenger Cars, Projected from the Last Fifty Years." Mr. Burnell delivered a talk "The Design and Development of an Engineer" before the Student Chapter of the A.S.M.E. at Notre Dame University, South Bend, Indiana. He also made this presentation February 23 to the University of Illinois Student Chapters of A.S.M.E., S.A.E., and the American Foundrymens Society.

On March 21 **Ralph O. Helgeby,** experimental engineer in the Automotive Engineering Department of AC Spark Plug, spoke on "Flying North of the Arctic" before a group meeting in the Community Presbyterian Church, Flint, Michigan.

Speaking at the March 31 meeting of Ohio Northern University's Mechanical Engineers Club in Ada, **J. M. Murphy,** section engineer in Frigidaire Division's Household Engineering Department, outlined "The Opportunity in Industry."

"The Development of Frigidaire Cycla-Matic Refrigerator" was outlined by **J. W. Jacobs,** section engineer in the Research and Future Products Engineering Department of Frigidaire, before the April 11 meeting of The Dayton Patent Bar Association.

Z. Arkus-Duntov, research development engineer in Chevrolet Motor's Vehicle Development Group, addressed the Michigan State College Student Section of the S.A.E. on April 14. The title of Mr. Arkus-Duntov's presentation was "The Development of an Engineer."

On this same date, **Robert Voshmik,** senior process engineer in the Production Engineering Activity of Fisher Body Division, appeared before the Y.M.C.A. Hannan Toastmasters Club in Detroit, giving "The Views of General Motors Research and Engineering."

Kenneth A. Meade, director of the Educational Relations Section, Central Office Department of Public Relations, served as chairman of the Annual Meeting of the Michigan Section of the American Society of Agricultural Engineers. The meeting—held on April 22—included various technical talks and a tour of the General Motors Technical Center.

Speaking to the students of Lakeview High School in St. Clair Shores, Michigan, as part of the Senior Career Day program held on April 21, **W. E. Adamek,** senior product engineer in the Product Engineering Activity of Fisher Body, talked about "Engineering as a Profession."

Paul W. Rhame, general manager of the New Departure Division, addressed the Connecticut Pi Psi Chapter, Pi Tau Sigma, on the subject "Opportunities for the Engineer in Management" on April 21.

On April 25, at a meeting at Stephens Institute of Technology, Hoboken, New Jersey, **William K. Steinhagen,** staff engineer in the GM Engineering Staff's Power Development Group, presented the talk "Engineers in the Automotive Industry."

William J. Lawson, project engineer in AC Spark Plug's Defense Engineering Department, completed two speaking appearances during April. On April 22 he talked on "Our Communist Allies—the Yugoslavs" at a meeting of the Genesee County Ground Observer Corps. On April 28 he described "The Life of an Engineer in Communist Yugoslavia" at a meeting of the Alumnae Association of Nazareth College.

Thomas A. Boyd, Research Laboratories consultant, completed two speaking engagements during the period covered in this report. On April 29 Mr. Boyd addressed the engineering students at University of Cincinnati, speaking on the topic "On Being an Engineer." On May 10, at University of Oklahoma, he presented the same talk.

Robert Hard, detail engineer in the Defense Engineering Department of AC Spark Plug, addressed the Michigan Archeological Society in Grand Rapids on April 30. He spoke on "The Middle Woodland Site in Western Michigan."

Several General Motors personnel participated in the May 7 meeting of the Michigan Section, American Society for Engineering Education, held at Michigan State College, East Lansing. **Harold M. Dent,** administrative chairman of the Cooperative Engineering Program at General Motors Institute, served as discussion leader for the question "What Should Mechanical Engineering Design and Analysis Include?" **George V. Grundy,** administrative engineer, Buick Motor Division, also was a discussion leader for the topic "Relations with Industry." Also taking part in this discussion by outlining present guidance activities was **Robert L. McWilliams,** engineer in charge of Canadian Operations, GM Engineering Staff. **Edwin L. Yates,** director of College and University Relations, Central Office Personnel Department, presented a "Report on the Engineering Council for Professional Development First Five-Year Program."

Lubrication and Bearings

Leland D. Cobb, manager of research and development at New Departure, addressed the American Society of Lubrication Engineers at Chicago on April 14. The subject of his talk was "Integrally Sealed Ball Bearings."

During the same meeting, **Arvid E. Roach,** supervisor, and **Alfred W. Schluchter,** research engineer, both of the Mechanical Development Department, Research Laboratories, presented two discussions on "A New Bearing Metal Theory in Which Lubrication Is a Factor."

David L. Clark, Jr., sales engineer located in the Los Angeles regional office of New Departure, recently gave a talk on "The Applications of Ball Bearings in Deep Well Pumps" before a group of salesmen and engineers from Peerless Pump Division, Food Machinery and Chemical Corporation, at Los Angeles.

Manufacturing Processes and Facilities

Delco-Remy Division was represented in several panel discussions at the S.A.E.'s Golden Anniversary Production Meeting and Forum held at the Netherland Plaza Hotel, Cincinnati, Ohio, March 14 to 16. In the panel discussion on "Chipless Production," **R. L. Kessler,** manufacturing manager, was panel leader; **W. P. Bowman,** process engineer, was panel secretary; and **C. A. Nichols,** manager of manufacturing facilities, served as a member of the panel. **J. Q. Holmes,** supervisor of Facilities and

Equipment, GM Manufacturing Staff, participated in the panel discussion on machine tools.

Albert W. Wendt, engineer in Delco Products' General Process Department, appeared before the Dayton Branch of the American Electroplaters Society on March 16. He talked on "The Conversion of a Chromium Bath."

Henry Michelsen, master mechanic of the Bristol, Connecticut, plant of New Departure, was a speaker at the 1955 conference of the Machine Design Division, A.S.M.E., held on April 6. The conference participants, meeting at New York University, heard Mr. Michelsen speak on "Production Considerations in Machine Design With Particular Reference to Such Products as Ball Bearings."

Claude M. Willis, safety director at Delco Products, chose industrial safety as his topic in two appearances during April. On April 6 he described "Preventive Safety" to the students of Central High School in Cincinnati, Ohio, and on April 19 he discussed "Safety As I See It" before a meeting of the Civitan Club of Dayton, Ohio.

"Use of Hydraulic Valves in Welding Equipment" was outlined by **W. E. Adamek**, senior product engineer in the Production Engineering Activity of Fisher Body, before the April 12 meeting of the American Welding Society in Detroit.

During the A.S.L.E. convention held in Chicago on April 14, **Richard P. Hunnicutt**, research metallurgist in the Research Laboratories' Mechanical Development Department, presented a discussion on "A Radioactive Study of the Metal Cutting Process."

At the April 15 meeting of the American Welding Society, held at Michigan State College, East Lansing, **Ralph R. McNitt**, production engineer in the Production Engineering Department at Oldsmobile Division, described "Welding at Oldsmobile."

Theodore P. Gobeske, industrial engineer in the Work Standards and Methods Engineering Section of the Process Development Section, GM Manufacturing Staff, participated in the program of the Industrial Engineering Conference held at Purdue University on April 21. Mr. Gobeske talked on "What Is New in Industrial Engineering."

Robert W. Truxell, supervisor of Oldsmobile's Methods Engineering Department, completed two speaking engagements during the period covered in this report. On April 29, at the Time Study and Methods Conference which was sponsored jointly by the Society for the Advancement of Management and the A.S.M.E. and held in New York City, Mr. Truxell discussed "Methods Improvement in Master Planning." Two weeks later, May 13, he took part in the Michigan State College Engineering Symposium. He outlined "Engineering Preparation for the Design of Manufacturing Equipment."

Quality Control

"Selecting the Multiple Sampling Plan to Fit the Job" was the title of the talk given by **J. Cecil Brown** before the Muncie Section of the American Society for Quality Control on February 17. Mr. Brown is supervisor of the Inspection Department of AC Spark Plug.

On April 2 **Leo J. Nartker**, superintendent of the Quality Control Department of Delco Products, appeared before the Columbus Section Clinic of the A.S.Q.C., discussing "Case Histories Using Correlation and Regression Techniques."

Arthur Bender, engineer in the Engineering Department of Delco-Remy, completed two speaking engagements during the period covered in this report; on April 29 he outlined the "Fundamentals of Statistical Quality Control" for the Ohio Council of Teachers of Mathematics, meeting in Bexley and on May 5 he discussed "Quality Control" at the meeting of the A.S.Q.C. held at Fort Wayne, Indiana.

Research and Testing Equipment and Facilities

During the American Chemical Society convention held in Cincinnati, Ohio, from April 4 to 7, **George J. Nebel**, research engineer in the Research Laboratories' Fuels and Lubricants Department, and **Paul L. Cramer**, assistant head of that Department, jointly gave a paper on "Ignition Temperatures of Lead Compound Carbon Mixtures."

The Research Laboratories was represented at the A.S.L.E. convention held in Chicago, Illinois, on April 13 and 14. On April 13, **Arvid E. Roach**, supervisor, **Carl L. Goodzeit**, research engineer, and **Richard P. Hunnicutt**, research metallurgist—all of the Mechanical Development Department—jointly presented the paper "Wear of Iron with Various Elemental Metals." The same day, Mr. Roach, in conjunction with **Dr. Paul F. Chenea**, Research Laboratories consultant from Purdue University, gave the talk "A Mass and Energy Balance for the Wear Process." During the remainder of the meeting Mr. Roach presented discussions on three papers entitled: "Survey of Wear Mechanism," "A New Method for the Determination of Attitude and Eccentricity in Journal Bearings," and "A High-Speed Friction and Wear Machine."

At the April 18 meeting of the American Electroplaters Society, held in Hartford, Connecticut, **Cleveland F. Nixon**, head of the Research Laboratories' Electro-Chemistry Department, read the paper "Outdoor Durability of Plated Parts."

J. M. Novajosky described "A Rugged and Efficient High-Speed Photographic Illumination System" at the 77th Semiannual Convention of the Society of Motion Picture and Television Engineers, Chicago, Illinois, April 21. Mr. Novajosky is an experimental and research engineer in the Electrical and Parts Test Mechanical Proof Test Group, Aircraft Engines Operations of Allison.

At the April 22 meeting of the Electrochemical Society, held in Detroit, Michigan, **J. Douglas Thomas**, senior research chemist in the Research Laboratories' Electro-Chemistry Department, described "The Measurement of Leveling with an Interference Microscope."

"The Arterialization of Blood as It Applies to the Mechanical Heart Problem" was the title of the paper given by **Calvin H. Hughes** of the Research Laboratories and **Dr. F. D. Dodrill** before the American Association for Thoracic Surgery convention in Atlantic City, held from April 24 to 26. Mr. Hughes is a research biologist in the Industrial Hygiene Department and Dr. Dodrill is associated with Harper Hospital in Detroit.

On April 27, at a meeting of the American Industrial Hygiene Association held in Buffalo, New York, **Kathleen Kumler**, chemist in the Industrial Hygiene Department, and **Thomas P. Schreiber**, research physicist in the Physics-Instrumentation Department, both of the Research Laboratories, outlined "A Rapid Method for the Spectrochemical Analysis of Lead in Blood."

Contributors to July-August 1955 Issue of GENERAL MOTORS Engineering JOURNAL

ROBERT R. CANDOR,

contributor of this issue's "Notes About Inventions and Inventors," is assistant patent counsel in the Dayton Office of the Patent Section, located at Frigidaire Division. He was originally employed by General Motors in August 1925 at the Patent Section's office in Washington, D. C., and was transferred as a patent attorney to the Patent Section at Frigidaire in November 1928. He was promoted to the position of supervisor of the Frigidaire Patent Section, Dayton Office, in 1952.

His original activities in connection with Frigidaire Division were directed mainly to the field of refrigeration. When it was decided that Frigidaire should manufacture other domestic appliances, Mr. Candor was assigned the patent responsibilities in connection with these other appliances. This required his major attention until his appointment to the position of supervisor in 1952.

Mr. Candor received the degree of bachelor of science in 1912 from the College of Wooster. For several years thereafter, he was employed as a sanitary engineer in and about Chicago. From 1917 to 1925, he was a patent examiner in the United States Patent Office, Washington, D. C. He is a member of the bar in Washington, D. C. and in the State of Ohio, and of the Dayton Patent Bar Association.

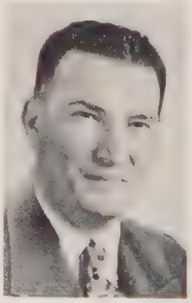
WILLIAM A. FLETCHER,

co-contributor of "A Summary of High-Speed Special Assembly Machinery Developed at Delco-Remy," is chief process engineer in the Process Department of Delco-Remy Division, Anderson, Indiana. In this position, he is responsible for the development of new and improved product manufacturing methods.

Mr. Fletcher originally joined General Motors in 1926 as a machinist in Chevrolet Motor Division's Flint, Michigan, plant which sponsored him as a cooperative student at General Motors Institute. He was graduated from G.M.I. in 1930. Two years previously, he was transferred to Delco-Remy. There, his first assignment was in the Process Laboratory and in 1938 he was promoted to process project engineer. He assumed his present position in 1951.

Some of Mr. Fletcher's previous major projects have included the development of press application to the cold-forming of automotive electrical parts, application of resistance welding techniques to automotive tubing, and engineering design work on servomechanisms. In summary, his work has encompassed almost all phases of process development work.

Twelve patents have been granted as a result of Mr. Fletcher's work in the fields of molding, welding, servomechanisms, presses, and specialized manufacturing machinery. His technical affiliations include membership in the Society of Automotive Engineers which has published one of his previous technical papers.



WALTER F. HELLER,

co-contributor of "An Investigation of the General Metallurgy of Aluminum-Base Aircraft Alloys," is assistant chief engineer at Harrison Radiator Division, Lockport, New York. Mr. Heller recently was transferred to Harrison Radiator from the Buick-Oldsmobile-Pontiac Assembly Division where he was located at the time of writing his paper appearing in this issue.

Mr. Heller joined the Kansas City plant of B.O.P. Assembly Division in 1951 as chief metallurgist and manufacturing development engineer for aircraft. At that time, the plant was organized to produce automobiles and aircraft simultaneously. In 1953 he was made director of quality control, which position he held until his transfer to Harrison Radiator Division.

Mr. Heller received the B.S. degree in electrical engineering in 1926 from Clemson College and later did graduate work in metallurgical and mechanical engineering. In 1928 he joined AC Spark Plug Division, Flint, Michigan, where he remained until 1944, attaining the position of chief metallurgist. While at AC Spark Plug, Mr. Heller was associated with the Process Engineering, Material and Production Control, Manufacturing, and Laboratory Departments. He has worked on varied process, equipment, and product projects, with outstanding developments in automotive and aircraft bearings and spark plugs.

Mr. Heller's engineering experience outside of General Motors includes work with the Michigan Bell Telephone Company, the Bethlehem Steel Corporation, and the Nelson Specialty Welding Equipment Company where he was technical director and executive assistant to the president.

Five patents in the fields of engineering design and metallurgy have resulted from Mr. Heller's work. His technical affiliations include membership in the American Welding Society and the American Society for Metals.

HAROLD E. HELMS,

who prepared the problem "Determine the Shear Loads and Bending Moments in a Statically Indeterminate Beam" and the solution appearing in this issue, is a senior project engineer in the Power Turbine Engineering Department of Allison Division, Indianapolis. The problem and solution he presents are typical examples of the everyday calculations performed in connection with his currrent major project of designing and testing structural components of the Allison turbo-prop aircraft engine.

Mr. Helms originally joined General Motors in 1943 as a junior detailer in the Engineering Department of Chevrolet Motor Division's assembly plant at Muncie, Indiana. He left this Division to enter Purdue University which granted him the B.S. degree in engineering mechanics in 1948 and the M.S. degree in the same field in 1950. While studying for his master's degree Mr. Helms served as an instructor in civil engineering and engineering mechanics.

After receiving his master's degree Mr. Helms joined the Argonne National Laboratories, Lemont, Illinois, where he did developmental work on the reactor component of the nuclear-powered submarine. He left this concern in May 1952 to join the Allison Division as a project engineer. In this capacity he was concerned with doing design and test work on structural components of the turbo-prop engines used as the power plant for the VTO (vertical take-off) type aircraft. He was promoted to his present position in June 1953.

Mr. Helms is a member of the Chi Epsilon civil engineering honorary engineering society and Sigma Xi. He also is a member of the Society for Experimental Stress Analysis, Institute of the Aeronautical Sciences, and is a registered professional engineer for the State of Indiana.

CURTIS P. KELLEY,

contributor of "Frigidaire Package-Type Air Conditioning Unit" is section engineer in the Research and Future Products Department at Frigidaire Division, Dayton, Ohio. Mr. Kelley has served in this capacity for the past seven years, his most recent work being the development of an automotive air conditioning system of which he writes in this issue.

Mr. Kelley joined Frigidaire in 1937 as a tester in the Commercial Engineering Department where he worked on compressors for commercial applications. In 1942 he was made a junior engineer and later in the same year he became plant layout engineer.

He served in this capacity until 1945, during which time he was connected with projects for the rearrangement of existing facilities and layout of new plants for Frigidaire's production of military equipment. In 1945 he was made product engineer and three years later was advanced to his present post. Among his previous projects have been the design and development of refrigeration for bottled beverage coolers.

Mr. Kelley is a graduate of the University of Kentucky, receiving the bachelor of science degree in mechanical engineering in 1936. He is a member of the Ohio Society of Professional Engineers, the Society of Automotive Engineers, and the Engineers Club of Dayton. He also is a member and past chairman of a General Motors subcommittee on automotive air conditioning.

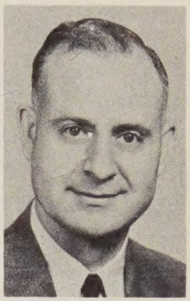
CHARLES A. NICHOLS,

co-contributor of "A Summary of High-Speed Special Assembly Machinery Developed at Delco-Remy," is director of manufacturing facilities of the Delco-Remy Division, Anderson, Indiana. In this capacity, Mr. Nichols is directly responsible for the activities of the master mechanic and plant engineering staffs, including process development, plant engineering and maintenance, and tool engineering.

A mechanical engineering graduate of the Carnegie Institute of Technology, Mr. Nichols started with Delco-Remy as a student engineer in 1923. Serving first as a plant foreman, he later was placed on special assignment. In 1927 he directed the installation of the Delco-Remy gray iron foundry—one of the first gray iron permanent molding foundries in the world. He served as superintendent of the foundry until 1930, when he was assigned to the process engineering staff where he later was made master mechanic.

Mr. Nichols was named Delco-Remy co-ordinator of defense production in April 1951 and was advanced to the position of factory manager over aircraft components production in August 1952. He was advanced to his present position in October 1953.

One of the results of Mr. Nichols' past work has been the granting of 12 patents in the field of special machinery. He is a member of the Society of Automotive Engineers, and the American Ordnance Association. He has published several papers in the *S.A.E. Journal* and other technical publications.



FRANKLIN L. RACINE,

contributor of "A Method for the Simultaneous Quantitative Analysis of Carbon and Sulphur in Steel and Cast Iron," serves as chief chemist in GMC Truck & Coach's Metallurgical Department, Pontiac, Michigan. His duties include supervision of the Division's chemical and spectrographic analysis work.

Mr. Racine joined the organization in 1929, doing repair work. In 1930 he transferred to the Blueprint Room and, one year later, to the Chemistry Laboratory. In 1933 Mr. Racine transferred to the Metallurgical Department as a chemist and five years later was promoted to chief chemist—his present position.

Mr. Racine studied qualitative chemistry and applied spectroscopy at Wayne University, Detroit, Michigan, and holds two certificates—one in chemical engineering and one in industrial metallurgy—from the International Correspondence Schools. His work with both qualitative and quantitative analytical methods led to a timesaving laboratory setup and procedure for determining simultaneously the amount of carbon and sulphur in cast iron and steel—the subject of his paper in this issue.

His technical affiliations include membership in the American Chemical Society and the American Society for Metals. In addition, he is a member of several General Motors technical committees—the GM Analytical Chemistry Committee, the GM Spectrographic Committee, and the GM Hazardous Materials Committee.

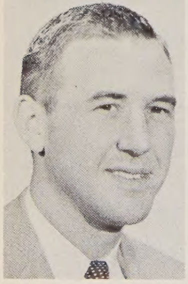
Contributors' backgrounds vary greatly in detail but each has achieved a technical responsibility in the field in which he writes.

HAROLD A. REYNOLDS, contributor of "Solving the Thermal and Structural Problems in Radiator Design for Automotive Cooling Systems," serves as engineering supervisor—Radiator Section at Harrison Radiator Division, Lockport, New York.

Mr. Reynolds began his General Motors career in 1919 as a senior checker for the Oakland Motor Car Company which had become a Division of GM ten years previously. In 1921 he completed a brief assignment on experimental car design at the Chevrolet Motor Division and during the same year, he transferred to Harrison Radiator. At this Division, he was promoted to assistant commercial engineer in 1926, to experimental engineer in 1928, to sales engineer in 1931, and to assistant chief product engineer in 1938.

Steam-cooled engine design, an artificial marble process, aircraft radiators, oil coolers, and designs of clutches, axles, and chassis for passenger cars and trucks are some of the major projects included in Mr. Reynolds' previous work. At present, he is concerned with passenger car, truck, tractor, and locomotive radiators, and automotive thermostats. His work in the field of heat transfer media, the subject of his paper in this issue, has resulted in four granted patents. He is the author of a published paper on the maintenance of automotive engine cooling systems.

Mr. Reynolds became a member of the Society of Automotive Engineers in 1913 and participates in four of its activities—the Coordinating Research Council, the Transportation and Maintenance Committee, the Cooling System Maintenance Subcommittee, and the Engine Subcommittee (chairman).



HOWARD E. SMITH, contributor of "The Ternstedt-Spray Process," is a project engineer in the Process Development Section of the General Motors Manufacturing Staff, located at the GM Technical Center.

In April 1941 Mr. Smith joined Delco-Remy Division in Anderson, Indiana, as an apprentice and later was enrolled as a co-op student at General Motors Institute. He continued at this Division until joining the Navy as an aviation cadet in July 1944. In September 1945 he returned to Delco-Remy, completing his four-year program at G.M.I. in 1946. He held the positions of laboratory technician, junior engineer, and engineering aide while at Delco-Remy.

In February 1948 he transferred to the Process Development Section where he was mainly concerned with various mechanical projects related to manufacturing facilities in General Motors Divisions. From November 1948 to September 1949 he was on military leave of absence, serving as an engineering assistant in the Army. Since his return to Process Development, he has been primarily associated with projects relating to electrostatic painting—the subject of his paper in this current issue. His thesis project at General Motors Institute—which led to his bachelor of industrial engineering degree in 1951—was in the field of electrostatic and non-pneumatic spray painting.

JAMES M. THOMPSON, co-contributor of "An Investigation of the General Metallurgy of Aluminum-Base Aircraft Alloys," recently transferred to Frigidaire Division's Engineering Laboratory as a metallurgical engineer after almost three years' service with Buick-Oldsmobile-Pontiac Assembly Division's Kansas City plant.

In 1952—directly after receiving the B.S. degree in metallurgical engineering from the Missouri School of Mines and Metallurgy—Mr. Thompson joined Buick-Oldsmobile-Pontiac Assembly Division in its Quality Control Laboratory. In July 1954 he was made supervisor—metallurgical processing, until transferring to Frigidaire in March 1955. It was during this period at the Kansas City plant of B.O.P. that he completed the laboratory work on the metallurgical investigation of aircraft aluminum alloys as part of the Aircraft Program on the F-84F Thunderstreak fighter-bomber—the subject of his paper in this issue.

Prior to joining General Motors, Mr. Thompson was employed by the Atlantic Refining Company in Philadelphia, Pennsylvania. From June 1946 to January 1948 he served in the U. S. Marine Corps as a field telephone wire chief, separating with the rank of corporal.

The *General Motors Engineering Journal* is a publication designed primarily for use by college and university educators in the fields of engineering and the sciences. Educators in these categories may, upon request, be placed on the mailing list to receive copies regularly. Classroom quantities also can be supplied regularly or for special purposes, upon request to the Educational Relations Section, General Motors.

Progress Reports from GM Locations

Hydraulic Device Aids Precision Bolt Tightening

The Cleveland Diesel Engine Division encountered a problem of precision bolt tightening in which a conventional torque wrench did not give the desired results.

A steel ring, which is made in two halves and clamped together by two bolts, is used to mount cylinders on an engine crankcase. To make certain that the ring is tight, that the load is evenly distributed, and that the torque on the clamping bolts is sufficient without overstressing them, a hydraulic bolt tightener was developed.

This device can be screwed on the bolt threads which project beyond the nut. The hydraulic pressure exerts a load on the bolts while the reaction is carried through the bolt nut washer to the clamping ring. A hydraulic pressure of 3,000 psi results in a bolt stretch corresponding to a bolt stress of about 40,000 psi. A chuck, which is built into the unit, screws the nut on its seat resulting in uniformly loaded clamping bolts.

Faith of the Engineer

I AM AN ENGINEER. In my profession I take deep pride, but without vainglory; to it I owe solemn obligations that I am eager to fulfill.

As an Engineer, I will participate in none but honest enterprise. To him that has engaged my services, as employer or client, I will give the utmost of performance and fidelity.

When needed, my skill and knowledge shall be given without reservation for the public good. From special capacity springs the obligation to use it well in the service of humanity; and I accept the challenge that this implies.

Jealous of the high repute of my calling, I will strive to protect the interests and the good name of any engineer that I know to be deserving; but I will not shrink, should duty dictate, from disclosing the truth regarding anyone that, by unscrupulous act, has shown himself unworthy of the profession.

Since the Age of Stone, human progress has been conditioned by the genius of my professional forebears. By them have been rendered usable to mankind Nature's vast resources of material and energy. By them have been vitalized and turned to practical account the principles of science and the revelations of technology. Except for this heritage of accumulated experience, my efforts would be feeble. I dedicate myself to the dissemination of engineering knowledge, and especially to the instruction of younger members of my profession in all its arts and traditions.

To my fellows I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerance and respect, and devotion to the standards and the dignity of our profession; with the consciousness, always, that our special expertness carries with it the obligation to serve humanity with complete sincerity.

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